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AN ERGONOMIC EVALUATION OF STAR-VUE AND NAV-ICE

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AN ERGONOMIC EVALUATION OF STAR-VUE AND NAV-ICE

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Un sommaire en francais de ce rapport est inclus avant la Table des matieres.

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17. Abstract

This report summarizes an assessment of several human factors aspects of NAV-ICE - a computer-based system which utilizes airborne radar (STAR-VUE), marine radar and other image data for ice navigation. The study focuses on the design of the user interface and a subsequent phase of the project explored the accuracy with which experienced ice observers could classify ice using digital SAR imagery. Two prototype display configurations were examined for use as training simulators. This work identified desirable changes and additions to the NAV-ICE system. It also pointed out the need for further research in the area of ice classification and training using SAR imagery.

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17. Résumé

Les travaux dont il est rendu compte ici concernent l'évaluation, du point de vue ergonomique, du système NAV-ICE; piloté par ordinateur, ce système est conçu pour la navigation dans les glaces et utilise une imagerie produite par diverses sources de télédétection, notamment les radars aéroportés et embarqués. La recherche a porté sur la mise au point de l'interface homme-machine et aussi sur la précision avec laquelle il est possible de classifier les divers types de glace en s'aidant de l'imagerie SAR numérisée. Deux types de visualisation réalisés en prototype ont été examinés sous l'angle de leur emploi comme outils de formation par voie de simulation. La recherche a mis en évidence certaines modifications ou adjonctio souhaitables ainsi que la nécessité d'approfondir davantage certains domaines spécifiques comme la classification des glaces et la formation de ceux qui ont la tâche de naviguer dans les glaces en s'aidant de l'imagerie SAR.

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SUMMARY

Several types of Arctic marine operations have benefited over the past few years from advances made to airborne and ship-mounted radars. Research conducted on the M.V. Arctic, and sponsored by the Transport Development Centre, has shown the value of using high-resolution synthetic aperture radar (SAR) for ships navigating in sea-ice. SAR imagery, like that available from INTERA's STAR-1, provides the best image characteristics and best level of information for use as an ice navigation chart. The ship's own marine radar, displayed on a bright TV-type monitor, can provide a means of tracking the position of the ship on the SAR imagery when ice conditions have changed.

The experience gained by studying how these data are used on-board icebreaking ships has resulted in the development of an integrated shipboard display system by INTERA called "NAV-ICE". The baseline NAV-ICE consists of: (1) INTERA's STAR-VUE, a new computer-based system designed to receive, store, and display airborne radar data; (2) MARINE-VUE, a bright marine radar display system; and (3) special functions for ice navigation. This baseline system has been designed to be easily expandable and capable of displaying other image data like that available from the NOAA satellites or new sensors like sonar.

This report summarizes an assessment of several human-factors aspects of the NAV-ICE system. The initial phase of the research project involved evaluating the STAR-VUE portion of this system, which was available in prototype form for shipboard testing. This assessment focused on identifying ways in which the user interface and software system could be improved or refined for shipboard personnel. This involved a formal task analysis followed by structured interviews and testing sessions with navigators and ice specialists who had varying amounts of experience with SAR data.

A subsequent phase of the project explored the accuracy with which experienced ice observers could assess and classify ice using digital SAR imagery displayed at several different resolutions on a STAR-VUE system. The purpose of this experiment was to answer several questions concerning the optimum design of the screen layout, display resolution, and amount of information required for ice classification using a video

display system like STAR-VUE, as well as its suitability for use as a simulator.

In addition, two prototype display configurations were explored for use as ice navigation training simulators. One system utilizes SAR and marine radar data that have been collected in the field and displays these data on a single screen. The second system, which shows great promise, actually simulates the marine radar data from digital SAR imagery.

An extensive literature review was also conducted, covering a wide range of topics associated with research and development of systems such as NAV-ICE. The resultant annotated bibliography is included as part of this report.

The direct consequences of this work are many. The STAR-VUE system proved to have several advantages over the older hardcopy display systems for shipboard use: in addition to being automated and highly user-friendly (the system can be mastered with very little practice), it provides many more tools for navigating in ice and data can be displayed at more than one resolution. It can also be used for training and can be programmed to display a variety of data in a self-study or tutorial fashion.

This work has identified desirable changes and additions to the STAR-VUE portion of the NAV-ICE system; these changes can help to: (a) avoid operator confusion and error; (b) make the system more useful for navigation and ice interpretation; and (c) increase operator acceptance of the system. Finally, and most importantly, this work has identified a need for further research in the area of ice classification and training procedures for those involved with ice navigation using SAR imagery.

SOMMAIRE

Les perfectionnements des radars tant aéroportés qu'embarqués ont eu des retombées bénéfiques pour la navigation dans les eaux arctiques. Le programme de recherche lancé par le Centre de développement des transports, et effectué à bord du N.M. Arctic, a mis en évidence l'utilité du radar à antenne synthétique (SAR) haute résolution pour la navigation arctique. L'imagerie produite par ce radar, et relayée à un système d'aide à la navigation comme le STAR-1 de la firme INTERA, fournit une information visuelle de la plus haute qualité. Quant au radar de bord, dont l'information est affichée sur des écrans de type télévision à forte luminosité, il permet de repérer le navire sur les images du radar aéroporté, au fur et à mesure que les conditions glacielles évoluent.

L'observation des méthodes selon lesquelles l'information radar est exploitée à bord des cargos brise-glace a débouché sur la mise au point d'un poste de navigation intégré appelé NAV-ICE, également réalisé par INTERA. Dans sa version de base, il comporte: 1) un nouveau sous-système piloté par ordinateur (le STAR-VUE), capable de recevoir, stocker et afficher automatiquement l'information du radar aéroporté; 2) un sous-système (le MARINE-VUE) affichant sur des écrans à forte luminosité l'information du radar de bord; et 3) diverses autres fonctions utiles à la navigation. En plus d'être hautement évolutif, ce poste permet d'afficher l'imagerie reçue d'autres sources de télédétection, comme les satellites NOAA et les sonars.

Les travaux dont il est rendu compte ici concernent l'évaluation ergonomique du poste NAV-ICE, à commencer par le sous-système STAR-VUE, réalisé en prototype aux fins d'essais à bord. Par cette évaluation, on a surtout cherché à mettre au point ce sous-système, en améliorant ou en affinant, dans une perspective ergonomique, l'interface homme-machine et le logiciel d'application. Pour cela, une analyse complète des tâches a été faite, suivie d'interviews formelles et de séances d'apprentissage auxquelles ont été invités le personnel de navigation et les spécialistes des glaces, plus ou moins familiarisés avec l'exploitation de l'information radar.

La phase suivante du programme a porté sur la précision avec laquelle les "observateurs des glaces" d'expérience ont pu reconnaître et classifier les divers types de glace, en s'aidant du STAR-VUE qui affiche une imagerie SAR numérisée, à différents degrés de résolution. Ces expérimentations avaient pour objet de trouver la réponse à plusieurs questions concernant l'agencement optimal de la visualisation, le degré de résolution et la quantité d'informations nécessaires pour reconnaître les glaces à l'aide du STAR-VUE. On a cherché également à reconnaître les possibilités du STAR-VUE comme outil de simulation.

En outre, deux types de visualisation réalisés en prototype ont été examinés sous l'angle de leur emploi comme outils de formation par voie de simulation. Le premier type combine les images des radars SAR et de bord, stockées lors de périples antérieurs, et les affiche sur un seul écran. Le deuxième, qui semble très prometteur, permet de simuler à partir des images SAR, celles qui seraient produites par le radar de bord.

Une recherche documentaire complète a également été faite dans plusieurs domaines reliés à la R&D en matière d'aides à la navigation, tel le système NAV-ICE. La bibliographie correspondante, dûment annotée, figure dans le présent rapport.

Les résultats directs de la présente recherche sont nombreux. Le système STAR-VUE se présente comme une meilleure aide à la navigation que les documents imprimés utilisés jusqu'ici. De plus, il est entièrement automatique et hautement convivial (l'apprentissage se fait rapidement); il multiplie les formes d'aide à la navigation dans les glaces et l'affichage peut se faire à plus d'un degré de résolution. Enfin, il constitue un très bon outil d'apprentissage individuel ou dirigé puisqu'il peut être programmé pour afficher toutes sortes de données.

Cependant, le STAR-VUE reste perfectible, des modifications étant envisagées pour: a) mettre l'opérateur à l'abri de toute erreur ou confusion; b) accroître l'utilité du système pour la navigation et l'interprétation des conditions glacielles; et c) mieux faire accepter celui-ci par les personnes chargées de l'exploiter. Enfin, et surtout, de plus amples recherches sont nécessaires, notamment dans le domaine de la classification des glaces et de la formation du personnel qui aura la tâche de naviguer dans les glaces en s'aidant de radars aéroportés.

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1. INTRODUCTION

With the growing commercial development of the northern offshore frontier areas and the growth of mining and other land-based activities in the high Arctic, a need has arisen for better and more reliable information on ice conditions for improved marine transportation. The use of remotely-sensed data, particularly airborne radars [side-looking airborne radar (SLAR) and synthetic aperture radar (SAR)], has expanded rapidly in recent years so that it is now possible for marine operators to obtain reliable all-weather information on ice conditions and hazards, even in the darkness of Arctic nights.

Transportation Development Centre (TDC) has undertaken an extensive research and development program with INTERA to ensure reliable and efficient navigation for ships operating in Canadian Arctic waters. This has resulted in the development of an integrated shipboard system called "NAV-ICE" that primarily uses airborne radar, along with marine radar imagery, for strategic and tactical ice navigation.

At the heart of NAV-ICE is a new, INTERA-built product for receiving, storing, and displaying airborne radar data, referred to as STAR-VUE. The shipboard equipment that has been traditionally used to receive and display SAR and SLAR data produces imagery on dry silver paper or film transparency. These transparencies are adequate for many applications; however, they do not present digital SAR data at full resolution and are limited in the number of grey scales available for display. Another problem with the downlink receiver is that data reception is a relatively complicated full-time task that requires a skilled operator.

STAR-VUE has been designed to allow these users to easily receive, store and display digital imagery. It is a microcomputer-based system with built-in telemetry receiver and video display. Geographically annotated airborne radar data, telemetered from the aircraft, are automatically received and stored on magnetic disk by the system. These images are viewed on a video display through adjustable windows. The STAR-VUE user interface has been designed for use by ships' officers with little or no knowledge of computers. Interaction with the system is via a trackball which moves a graphical cursor on the screen. Soft buttons on the display are used to traverse the multi-level menus for command and operation selection.

The addition of a MARINE-VUE bright marine radar display system, along with special functions for ice navigation, results in the baseline NAV-ICE system. Figure 1 presents a schematic diagram of the proposed NAV-ICE system and its components. Included in this drawing is a third display system, yet to be added, which would allow a ship to receive visual and infrared satellite imagery from the NOAA polar orbiting satellites.

Several types of Arctic marine operations have benefited recently from the introduction of these new systems and concepts. These operations include: (1) ice management support of exploratory drilling operations; (2) seismic vessel support; and (3) navigation support for icebreaking ships. The need has also arisen for a better understanding of how these systems will be effectively used and also for the development of training procedures required for their operation.

The research reported here was conducted to assess the NAV-ICE system, from the human factors perspective, during its design and development. The research team consisted of a group of human factors experts from the University of Calgary, Department of Psychology, along with the INTERA systems development team.

The first phase of the project was designed to evaluate the STAR-VUE (SAR) portion of the system, which was available for laboratory testing prior to the commencement of the research and is currently available for shipboard use.

Results of this initial assessment generated recommendations regarding the alteration of the STAR-VUE user interface and software system to

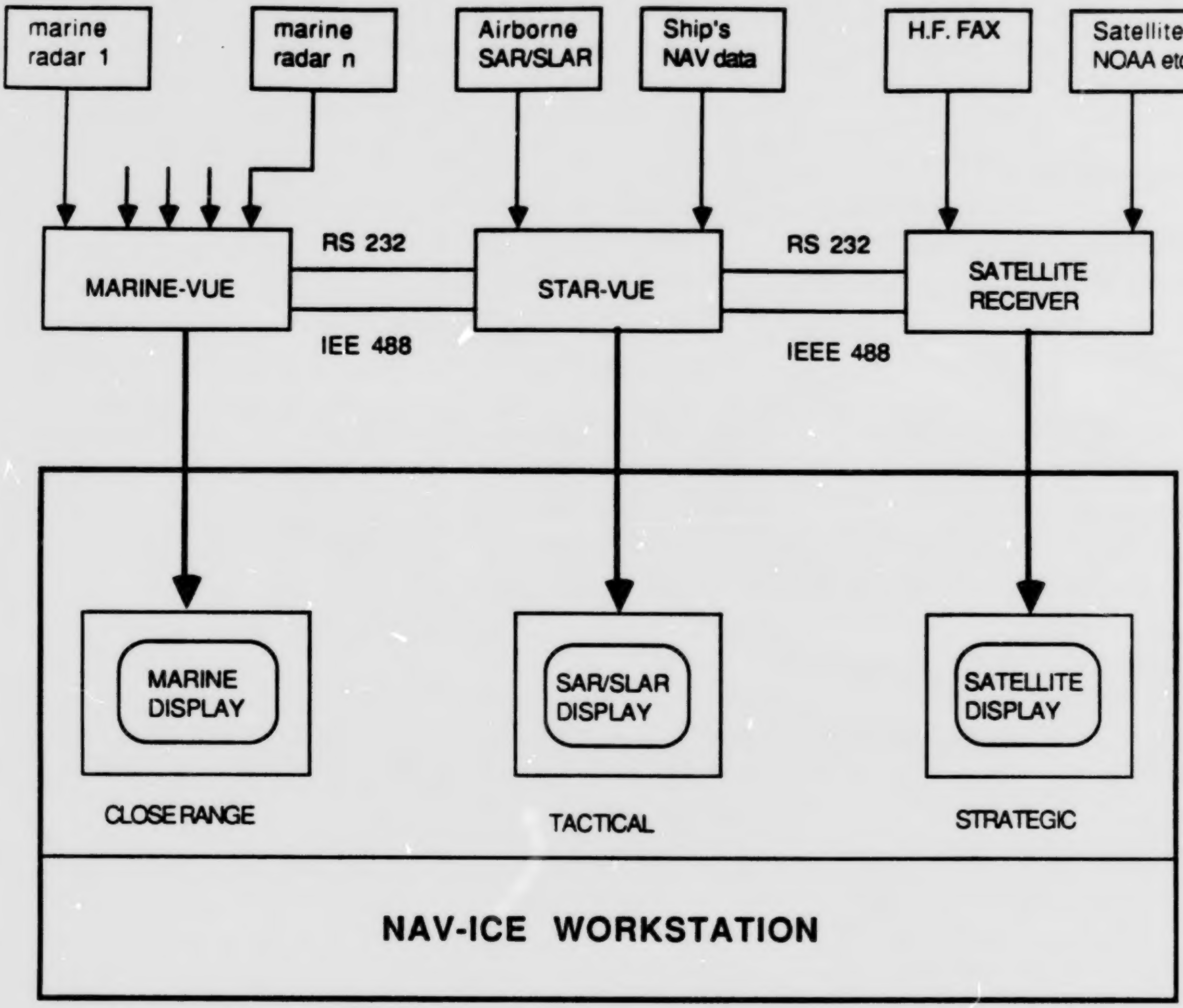

marine radar 1
marine radar n
Airborne SAR/SLAR
Ship's NAV data
H.F. FAX
Satellites NOAA etc.
RS 232
RS 232
MARINE-VUE
STAR-VUE
SATELLITE RECEIVER
IEE 488
IEEE 488
MARINE DISPLAY
SAR/SLAR DISPLAY
SATELLITE DISPLAY
CLOSE RANGE
TACTICAL
STRATEGIC
NAV-ICE WORKSTATION

FIGURE 1 CONCEPTUAL DIAGRAM OF THE NAV-ICE SYSTEM

further optimize STAR-VUE's compatibility with the human user for navigational purposes. The development team incorporated as many of these recommendations as possible into the STAR-VUE system during the project time-frame. The prototype system was also employed in training sessions for ships' personnel likely to be interacting with STAR-VUE during field-testing on the M.V. Arctic and on Coast Guard ships. These training sessions provided the final information on which the ergonomic evaluation of the system was to be based and resulted in a number of further recommendations which were also implemented by the development team.

The second phase of the project was to be conducted concurrently with Phase 3, shipboard testing of STAR-VUE. Unfortunately, it was not possible for the human factors researchers to travel on the M.V. Arctic for Phase 3 of this program. The research was carried out instead at the INTERA laboratory, using a twin of the prototype occupied for training purposes in Ottawa and for shipboard tests. This work explored the degree to which experienced ice observers could be expected to classify ice according to its age and salient features efficiently, accurately and with confidence from STAR-VUE imagery. Over one hundred SAR images of different ice conditions were incorporated into the STAR-VUE testing system. This research led to several significant results concerning the problem of ice classification using SAR data.

Several prototype system display configurations were developed and evaluated for use as training simulators during this study. A separate display system was developed to view SAR and marine radar data on the same screen and a second to simulate the marine radar data from SAR.

The fourth and final phase of the project, which is still ongoing, is the incorporation of the shipboard results into the comprehensive NAV-ICE system.

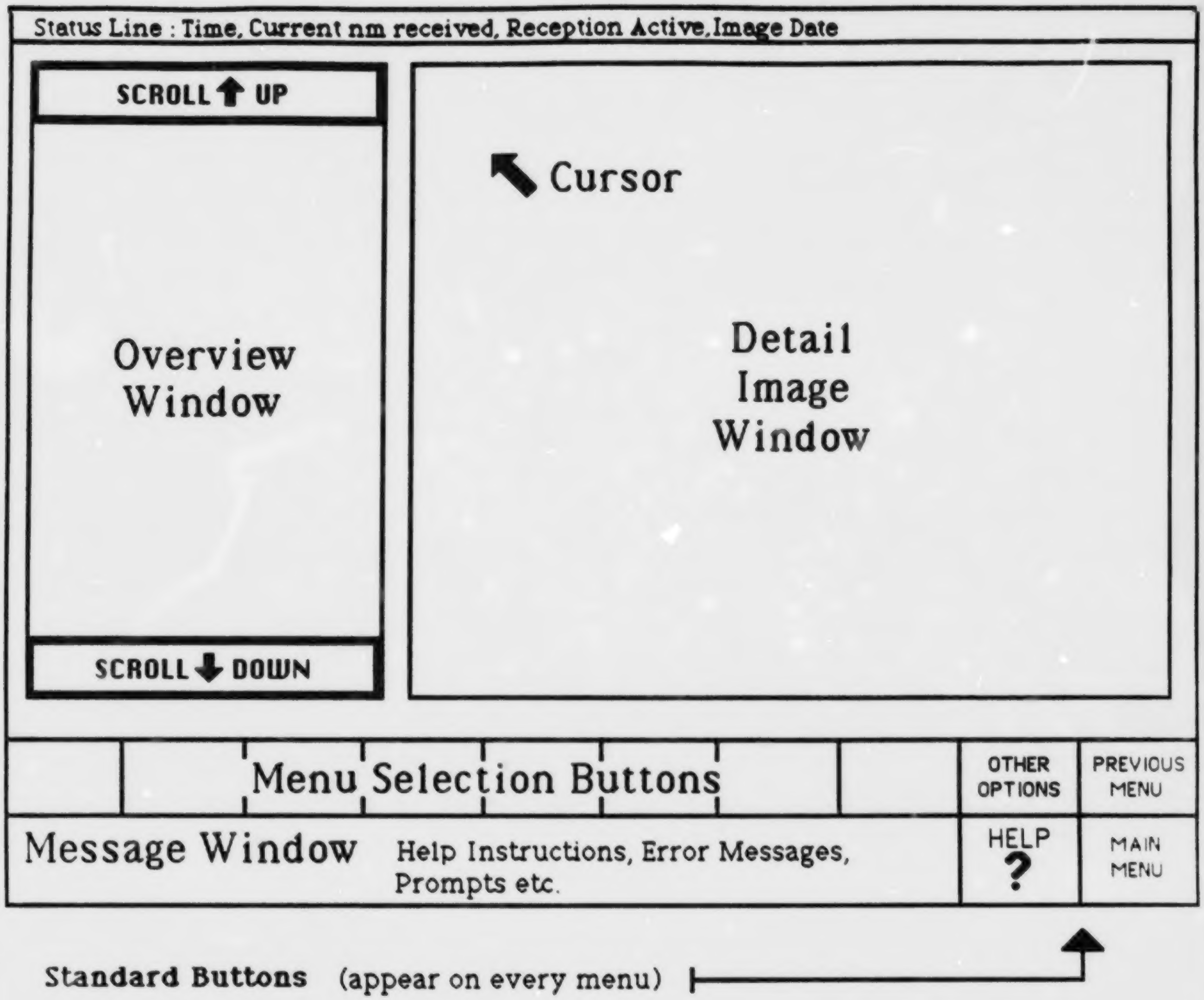
An extensive review of literature covering a wide range of topics associated with research and development of systems such as NAV-ICE was also conducted. The resultant annotated bibliography is included as part of the report.

This report is divided into sections which outline in detail the work that was performed in this assessment. Sections 2, 3 and 4 describe the ergonomic evaluation of STAR-VUE and the human factors testing that was done in Calgary and Ottawa. Section 5 presents the conclusion of this ergonomic evaluation. Section 6 outlines the ice classification study and Section 7 discusses the simulator aspect of the program. Section 8 presents the final conclusions of this report. It should be pointed out that because each of these sections is rather detailed and self-contained, readers may proceed directly to their section of interest with very little problem.

2. ERGONOMIC EVALUATION OF STAR-VUE: INTRODUCTION

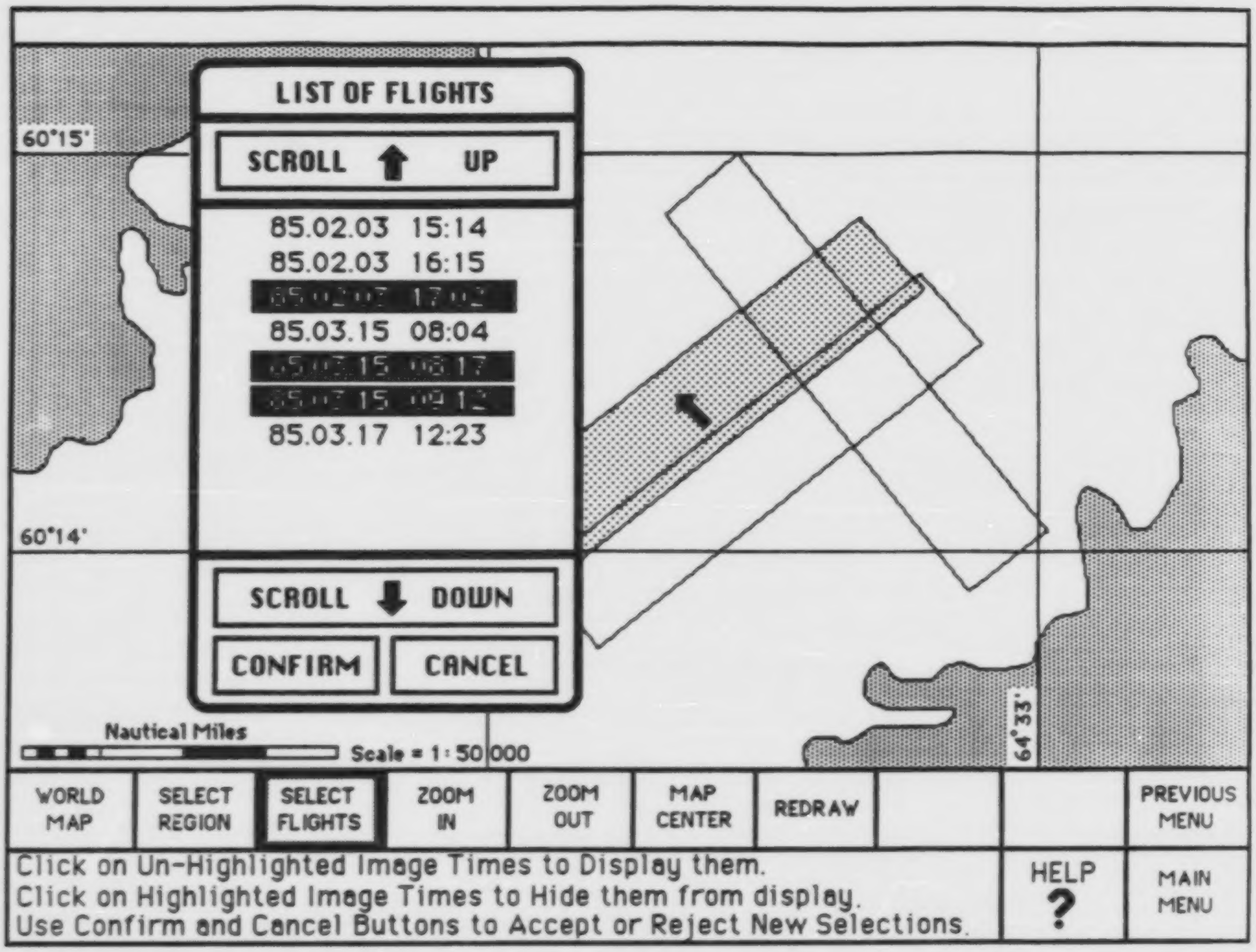
STAR-VUE is a real-time image reception and display workstation for SAR and SLAR radar imagery. A radar image may be received in " real time" as the aircraft is actively imaging, or transmitted to or from another STAR-VUE workstation. The downlinked imagery can be examined as it is being received on a graphics display, or can be stored for later viewing. The screen displays a row of 'soft' buttons, where a series of menus are shown for selection of options, positioned below an area for maps and imagery. The STAR-VUE screen layout is shown in Figure 2. The operator interacts with the display by means of both a rollerball, which enables movement of cursors around the screen, and a button to initiate selected operations. Different cursors perform different functions, i.e., one selects menu options, another roams across the image to select an area of interest and a third draws lines on the image to plot a ship's course. For example, a selection from the main menu allows an operator to view a map which shows the positions of any available flightlines (Figure 3). With the cursor, he can then select a flightline for display. Activation of another menu button displays the SAR imagery of that flightline on the left-hand portion of the screen for global viewing and strategic planning. A cursor box can be moved to any location on the image to choose an area for higher resolution display, in order to make tactical decisions, on the right-hand side of the screen. Another menu then enables a route to be drawn on that image. The user interface is designed to be easily operated by those who have had little or no previous interaction with computer systems.

Prior to preparing a protocol to be used in the development of training and testing procedures for interaction with STAR-VUE, a task analysis was carried out by the experimenter. All functions involving the screen, rollerball and operating buttons were examined to explore the nature of the tasks necessary for interaction with the instrument. The "STAR-VUE User Interface Description" (INTERA, June, 1985) acted as a guide for this process, which was a detailed description of each button in the menu


Status Line : Time, Current nm received, Reception Active, Image Date
SCROLL ⬆ UP
Overview Window
SCROLL ⬇ DOWN
Cursor
Detail Image Window
Menu Selection Buttons
OTHER OPTIONS
PREVIOUS MENU
Message Window
Help Instructions, Error Messages, Prompts etc.
HELP ?
MAIN MENU
Standard Buttons (appear on every menu)

Help ?	help cursor appears; next pick gets info
Main Menu	return to the primary menu
Previous Menu	return to the parent menu
Other Options	pop-up menu for other secondary choices

FIGURE 2 STAR-VUE Main Menu With Labelled Features


LIST OF FLIGHTS
SCROLL UP
SCROLL DOWN
CONFIRM
CANCEL
60°15'
60°14'
64°33'
Nautical Miles
Scale = 1 : 50 000
WORLD MAP
SELECT REGION
SELECT FLIGHTS
ZOOM IN
ZOOM OUT
MAP CENTER
REDRAW
PREVIOUS MENU
HELP ?
MAIN MENU

85.02.03 15:14
85.02.03 16:15
85.02.03 17:02
85.03.15 08:04
85.03.15 08:17
85.03.15 09:12
85.03.17 12:23

Click on Un-Highlighted Image Times to Display them.
Click on Highlighted Image Times to Hide them from display.
Use Confirm and Cancel Buttons to Accept or Reject New Selections.

Figure 3 STAR-VUE Select Region Dialogue Box

network, including instructions for functional operation of the system. The experimenter outlined the function, tasks involved in operating that function, and any obvious problems for each button for all menus. This served to familiarize the experimenter with the interface, to form the basis of a training procedure and to gain initial feedback from the experimenter, who was a naive user. The main menu was comprised of three buttons, allowing access to a 'world map' displaying available flightlines (IMAGE INFO), a SAR image of any incoming flightlines (VIEW RECEPTION), or the image of any selected flightline (VIEW IMAGE). For each of these displays, the accompanying menu appeared at the bottom of the screen. Buttons on these menus enabled the operator to carry out various functions as necessary. For example, to select an area of the SAR image shown on the left of the screen in VIEW IMAGE, the operator would select a button entitled ROAM, move the 'roam box' across the image, paste the box down where desired and then choose the resolution at which it should be displayed by using the ZOOM IN or ZOOM OUT buttons. DISPLAY DETAIL would then present the selected area at the selected resolution in the window on the right side of the screen.

Having become familiar with the system by means of the task analysis, the experimenter carried out four pilot interviews with INTERA employees. On the basis of their comments and the task analysis, the interview and training protocol were then developed.

3. HUMAN FACTORS EVALUATION OF STAR-VUE:

Assessment 1. Canarctic, Coastguard and Gulf Personnel

Testing sessions with each of seven subjects were between 90 and 120 minutes in duration. The four Canarctic subjects expected to sail on the M.V. Arctic in May, 1986 and were therefore motivated to envisage its operation in an applied setting. The interviews were followed by a group discussion at which the subjects were joined by a number of people from the INTERA STAR-VUE team.

The STAR-VUE functions which were employed in the study were IMAGE INFO, VIEW IMAGE, VIEW RECEPTION and RANGE AND BEARING. A method for graphically selecting flightlines using the arrow cursor was in operation and three alternative flightlines were displayed on the world map.

3.1 Method

3.1.1 Subjects

Canarctic Personnel:

A. Ship's Captain on the M.V. Arctic for 7 years. Extensive previous experience at sea. Has worked in all Canadian Arctic waters. Ice advisor.

B. Second Officer, younger, mainly experienced in Southern seas. Has been on the M.V. Arctic for one season. Very little experience of ice navigation.

C. Manager of Research and Development. Many years of experience in Canadian Arctic and researching the problem of ice navigation.

D. Research. Remote sensing background. Spent three seasons on M.V. Arctic, since Spring of '84. Responsible for implementation of STAR-VUE on ship.

Coast Guard Personnel:

E. Ship's captain on Coast Guard vessels for twelve years; has used SLAR data in hardcopy form for six years. Has been in all parts of the arctic.

F. Ship's Captain for 42 years,14 of which have been in Arctic waters. No experience of SAR or SLAR imagery at all.

Gulf Personnel:

G. Coordinator of rig vessels for Gulf. Has made use of SAR imagery since 1980.

3.1.2 Procedure

Subjects were seated beside the experimenter at the STAR-VUE workstation facing the screen. During the session, subjects were familiarized with the display and controls, interviewed prior to their participation in the training trials, tested on several tasks, and finally were reinterviewed at the end of the session. Each session was subdivided into four parts: the initial interview, training, testing, and the post-experimental evaluative interview.

3.1.2.1 Initial Interview

This was a discussion designed to establish the pre-test expectations and background of each subject and to discover the limitations of ice navigation equipment being presently used. Questions were asked regarding: (a) subject's background; (b) past use of equipment; (c) user requirements of STAR-VUE (tailored to suit each subject based on information from (a) and (b)); and (d) attitudes to and experience with computers versus hardcopy.

3.1.2.2 Training

The experimenter showed each subject through the operation of STAR-VUE according to a predetermined protocol . All operations were carried out by the subject according to instructions from the experimenter. During this interaction, a series of questions were asked relating to ease of operations and STAR-VUE images.

3.1.2.3 Post-experimental interview

This included any remaining questions about operations and images and discussion of possible alternative design features of the system and of any problems arising during interaction. In the case of the Canarctic and Coastguard groups, this was supplemented with a meeting at which all four subjects and several others were present.

The questions asked involved: (a) the visual display; (b) the image; and (c) the subject's attitude.

3.2 Results and Discussion

Subjects' answers and further comments and experimenter's observations were initially recorded on a form. From these, all comments were amalgamated in a comprehensive report of results. The following is a summary of the reports for Canarctic, Coast uard and Gulf.

3.2.1 User Requirements of STAR-VUE

1. The task and use of equipment for ice navigation can be described as follows:

    a) for strategic planning over days, satellite information is used to determine weather conditions. This low resolution used to determine weather conditions. This low resolution information is viewed by means of a VIEW-FAX interface by which different parts of the satellite picture can be examined;

b) for strategic and tactical planning over hours, marine radar and SAR/SLAR images have been used, mainly by a research team, while the operational people have used the traditional navigational charts and manual course-plotting, sometimes with reference to an overview projected image of SAR/SLAR data; and

c) for planning over minutes, binoculars and searchlights are used to detect close-range hazards.

2. Problems with the past use of SAR and SLAR hardcopy have included:

a) coordination between ship and aircraft to determine flight paths and have them delivered in time to be useful;
b) bulkiness of the images and the equipment necessary to produce them;
c) intensive labour in producing the images on the ship;
d) problems with inconsistent signal reception;
e) problems with equipment breakdown and the messiness of the printing materials; and
f) the limitations of being unable to change the scale of the image when necessary.

3. Navigating a Coastguard vessel is an entirely different job from steering a ship like the M.V. Arctic:

a) The Coastguard ships spend the majority of their time servicing outlying regions of the arctic coastland and therefore are often close to shore where the currents and ice movement are different from those on major sea crossings. Problems of navigation include the possibility of grounding and hitting rocks underwater.

b) The Coastguard ships are able to turn much more quickly than is the M.V. Arctic. Therefore, navigation involves looking at a slightly different area of ice in plotting a course.

4. Not all Arctic Coastguard vessels are in ice often enough to need more than the existing navigation tools. There is little prospect of ships operating in winter. On ships in the Eastern Arctic and the Gulf of St. Lawrence, aids to ice interpretation may be necessary.

5. For the purposes of rig surveillance (such as that performed by the subject from Gulf), it is highly important to have the MOSAIC function of STAR-VUE in operation. This function will take two or more adjacent flightlines and display them together on the screen, thus enabling the ice interpreter to look at a large area at one time. For Gulf, their entire operational area (180 x 70 miles around the rig) could be represented in SAR imagery as often as required, which would usually be once a day.

3.2.2 Training and Documentation

1. Attitudes to computers can be a problem. Some officers might be reluctant to take seriously the information STAR-VUE and the SAR images are providing.

2. It was apparent that in general, the attitudes of the operations people interviewed differed from those of the research people towards the ice navigation task. The ship's captain and second officer imagined that they would still spend a major proportion of their time looking out of the window for information and would use STAR-VUE only for reference now and then. The researchers, on the other hand, were obviously preparing to navigate "blind" under some weather conditions and at night. They see STAR-VUE and marine radar taking up one person's time exclusively. Thus, it may be necessary for the appropriate attitude to be emphasized in any training programme .

3. The training for users of STAR-VUE previous to the voyage should involve several days (3 to 5) and should include:

a) Background and rationale for the real-time downlink from the aircraft to the STAR-VUE system;
b) "Hands-on" session with STAR-VUE;
c) Interpretation of images and necessary cautions. For example, the STAR-VUE SAR image does not necessarily pick up all potentially hazardous icebergs, and since the ship's position on the SAR image is relative to the ice, geo-referencing by way of the latitude and longitude grid may be misleading; and
d) Pattern-matching exercises with STAR-VUE and marine radar images.

4. It is important for documentation to be as simple as possible. Ships' operators have a mass of documents available for all the equipment on the bridge and very little time to read it; thus the less need for recourse to a manual the better.

5. The user's manual should include a good schematic representation of the menu structure.

3.2.3 General

1. A number of questions cannot be answered until STAR-VUE is observed in use in the field. Ice interpretation is a skilled job requiring experience. It will depend on the ice conditions, the season, the quality of return, etc.

2. In the Western Arctic, STAR-VUE may be useful for one or two weeks of the year. Spring and summer are usually no problem, but fall conditions starting in mid-September can be dangerous. The large icebergs appear in the Eastern Arctic. If STAR-VUE is to be tested on Coastguard ships, it should be on the maritime and Laurentian ships

first, since these encounter the most severe ice conditions.

3. STAR-VUE would be a useful training tool for cadets and junior officers, but the ship's operators would still use vision and marine radar as tools for tactical navigation. SAR data cannot be used for navigation. It is strictly an aid to ice interpretation.

4. Programmers and STAR-VUE designers should spend some time aboard a Coastguard ship, because it is entirely different from, for example, the M.V. Arctic.

5. STAR-VUE gives ships' operators the chance to interpret the ice themselves, which is much more preferable to receiving the AES ice charts.

6. How much information can be stored on disc? May need to be able to see all a.m. and p.m. flights for several days.

7. Another attitude problem is the temptation to take all the information too seriously and not to appreciate, for example, that the ice on the screen has moved since the image on STAR-VUE was collected.

8. Light emission from the STAR-VUE screen may interfere with night vision on the ship.

9. The possibility of using two screens will be kept in mind. Although it was not thought to be necessary by the Canarctic members interviewed, there was some discussion with Martin Luce about showing a larger portion of the swath on one screen at two or three alternative scales, then a display window on another screen.

Given the present configuration of the single screen, it would be desirable to have a choice of two or three alternative resolutions for the overview image.

4. HUMAN FACTORS EVALUATION OF STAR-VUE:

Assessment 2. Training Sessions at Canarctic Offices, Ottawa.

Training sessions were held with four ship's captains and four ship's officers at the Canarctic offices in Ottawa. All were to sail on the M.V. Arctic during the summer months (May-October, 1986). The eight officers were introduced as a group to the functions and operations of STAR-VUE by means of a demonstration. Later that day, groups of three or four officers observed while another interacted with STAR-VUE, assisted by the investigator and two INTERA systems analysts when required. On the following day, each officer independently operated the system, familiarized himself with the tasks provided by the investigator and generated comments as he worked. The tasks were similar to those presented in detail earlier in the report (Section 3.1.2), but were conducted less formally than at the INTERA laboratory. The results of this evaluation are summarized in the following chapter.

5. CONCLUSIONS AND RECOMMENDATIONS: STAR-VUE

The testing and interviewing of employees from INTERA, Canarctic, Gulf and Coastguard resulted in a number of supportive statements praising STAR-VUE and also pointed out some problem areas with the system which required further research. Following discussions with the human factors research team, the STAR-VUE designers implemented a number of software changes to alleviate the problems experienced with the work station.

This chapter summarizes the positive attributes of the system, outlines the changes made to the system under this program, and describes some of the problems requiring further research.

5.1 Positive Attributes

STAR-VUE is highly 'user friendly'. The controls are very simple to use and can be mastered with very little practice. The controlling hand never needs to leave its position on the rollerball and buttons; therefore, a shift of attention is not necessary. The alternatives, such as hard-panel choice buttons, touch-sensitive screen, etc., were not thought to be preferable. The current screen layout and use of colour was generally well received.

STAR-VUE allows operators the chance to interpret the ice themselves, which is much preferable to receiving the AES ice charts.

COURSE AND DISTANCE is the most important function of the system, enabling the operators to actively use the imagery.

STAR-VUE, as opposed to SAR hardcopy, facilitates learning about the imagery because it is possible to take a closer look at any portion of the swath to test hypotheses about the ice conditions. Therefore, STAR-VUE should be a valuable training aid for ice interpretation.

The screen and overview sizes are adequate. Even in open water, the ship can only travel about 200 miles in a day. In ice, more than one overview in a day would not be required.

The ANNO ON/OFF function will be useful for position location, scale and orientation.

The print function will be useful for retrospective analysis of voyages. It may also be used for 'mosaicing' until the mosaic function is active. Note that the current print function allows hardcopy products to be generated from imagery being downlinked and from imagery stored on the system on an EDO Western Plotter.

The mosaic function will be particularly useful for oil-rig use, where the imagery is taken from a wide but constant area.

5.2 Changes and Additions

The following recommendations have been implemented as part of this study.

5.2.1 Main menu

An introductory START facility, whereby some sort of introduction to the system appeared on the screen at the beginning of the interaction, was viewed positively by the operators.

IMAGE INFO was replaced by SELECT IMAGE and the menus were changed accordingly.

RANGE AND BEARING seemed inappropriate on the main menu, since it labels an operational function, whereas the other three (IMAGE INFO, VIEW IMAGE, VIEW RECEPTION) describe viewing functions. RANGE AND BEARING was moved to the VIEW IMAGE menu and changed to COURSE and DISTANCE to better describe the actual operations performed.

5.2.2 IMAGE INFO (now renamed SELECT IMAGE)

The term "SELECT FLIGHTS" was changed to avoid confusion concerning the function of the button. The term "LIST STORED FLIGHTS" was chosen instead.

The speed of the map drawing was improved, as was the REDRAW response, by reducing the number of scales available for display. Not all eight 'world map' scales were necessary and some of the largest were eliminated. Scales were altered until only four remained. However, subjects indicated that the largest scale was not large enough, so two additional 'world map' scales larger than the current maximum of 1: 500,000 were retained.

In the message window, commas have been placed among the zeros for easier reading of scale values. 'Degrees' and 'minutes' can be expressed either numerically or symbolically.

It is now possible to access VIEW IMAGE from the IMAGE INFO menu.

Menu changes are sometimes so quick that they are imperceptible. This was solved by introducing a time delay and a brief period during which the menu buttons are blank.

When operations were carried out while the system was drawing maps, two kinds of problems arose: because the drawing function was rather slow, the operator sometimes concluded that he had not activated the function and clicked again. This caused the map to disappear as soon as it had been completed and to start drawing a second time, increasing the delay. In addition, some combinations of operations also seemed to lead to system failure or to meaningless displays. These circumstances have been improved by accelerating the speed of the map drawing and making the system more robust in this area.

When selecting flights with the arrow cursor, it was found useful to have the flight parameters displayed while the flightline is highlighted, perhaps in the message window. This has recently been implemented.

A list of available 'world map' scales was installed in the 'help' facility. Several people felt that it was laborious to click through all the 'zoom's to find out which scales were available.

The list of stored flights have been labelled to correspond to labels on flightlines displayed on the world map and to provide enough information to enable the operator to identify the location of each flight.

The LIST STORED FLIGHTS pop-up menu was too big and was also centrally located on the screen, thus obscuring the picture behind it. It was reduced in size and is now a less significant part of the screen.

5.2.3 View Image

Speed of response of the DISPLAY DETAIL button has been increased.

The display detail image can now be retained while referring to other menus, enabling an image to be saved when exiting and re-entering VIEW IMAGE.

It was agreed that the flightlines should be entered in the overview window as closely to their true orientation as possible. The end of the flightline swath falling to the north of a straight west/east orientation would appear at the top of the overview window, irrespective of whether or not that part of the image was the beginning or the end of the transmission.

Distances can now be expressed in nautical miles and meters.

'Minimum cursor size' now reads 'minimum box size'.

A scrolling function to move imagery in the overview window has been implemented. An overview image can be scrolled both horizontally and vertically with the use of the scrolling function. This is certainly an advantage over the current, more static display function.

A North arrow can now be placed on both the overview and the display window images.

Knowledge of the identity of the flightline being viewed at any time is provided in the message area.

5.2.4 Range and Bearing

Choice of cursor symbol could be more consistent. The RANGE AND BEARING cursor was changed to match the map centre, "cross-hair" cursor.

COURSE AND DISTANCE was chosen as a more appropriate label than RANGE AND BEARING. The functionality of this menu choice was expanded to plot the ship's actual (past) course with a coloured line, the ship's proposed course with another coloured line, and range and bearing to selected targets with another coloured line. Ship's course can also be plotted on either the overview or the detail window. Line segments appear on the overview window as they are being drawn on the display detail window.

The distances appearing in the message window, which were one or two decimal points out, have now been corrected.

The course parameters are rounded off to the nearest degree since minutes are redundant.

The three buttons on the control unit will be clearly labelled 'go',' stop' and 'help'.

The roam box now also appears on the overview window while the COURSE AND DISTANCE menu is active.

The segments were in some cases difficult to see, thus the lines have been made slightly thicker.

The speed at which the segments appear on the screen when drawn has also been increased.

The yellow lines of SELECT ACTUAL ROUTE were indistinguishable from the green highlighted segments. A third red line was added to improve this functionality.

5.3 Further Laboratory Research

The Human Factors group made a valuable contribution to the STAR-VUE development and generated a number of recommendations to improve the system. It was not possible, however, to implement all suggestions in the time-frame of the program. The following is a partial list of recommendations which emerged from this research and should be considered for future programs. It should be pointed out that STAR-VUE is currently undergoing a series of shipboard trials on the M.V. Arctic, which may address some of these anticipated problems.

It was recommended that alternate configurations for the menu buttons and message window be considered in the future. One suggested approach would be to compare the use of the current layout to one which arranged the buttons in a box on the bottom left-hand side of the screen, while the message window appeared in the bottom right-hand side. The alternatives could be compared by asking operators for their preference and by comparing performance efficiency.

When the menu system is completely developed and includes the proposed MOSAIC and PLAN COVERAGE menus, it will be more complex, which may require some further investigation. For example:

1. How long will it take to learn the range of functions available?
2. What form should a schematic representation of the menu system take and where should it be available?
3. How confusing is the system to a novice?
4. To what extent should the menus be hierarchically organised as

opposed to being interconnected?

The apparent inconsistency in the use of the centre button to stop the DRAW SEGMENT operation should be kept in mind and alternatives considered.

The question of using colour to denote different intensities in SAR images can be explored experimentally. Colour assignment is now available on STAR-VUE in the form of an interactive look-up table. However, some problems with colour assignment are: (1) maintenance of colour consistency between images and within parts of an image; and (2) the assignment of colour on a continuum from bright to dark which may be misleading, since a bright return does not necessarily indicate thick ice.

The process of matching the SAR image with the marine radar image for position location involves mental rotation, memory, feature detection and matching. The single screen ensemble display of adjacent STAR-VUE and marine radar images, which is now operational, will enable the complex operations underlying navigational decisions dependent upon both sources of input to be investigated. For example, the current ability of the system to rotate the marine radar image to match the coordinates of the adjacent SAR image will allow the matching process to be scrutinized in a manner not before possible.

5.4 Recommendations Requiring Shipboard Research

After reviewing the results of the human factors studies conducted at INTERA and the Canarctic offices, along with the recommendations and problems presented above, the research team produced a set of questions and hypotheses to be investigated aboard ship in Arctic conditions. Unfortunately, it was not possible for a member from the human factors group to administer these questions on the M.V. Arctic this year. However, INTERA continues to pursue this work under continuing contracts with Canarctic for the ship-board testing of STAR-VUE. The following types of information are required:

5.4.1 Image Information

Does the 'world map' cover a suitable area or would a smaller regional map be preferable?

How many flightlines are there? Is use made of the LIST STORED FLIGHTS function?

Which scales are appropriate/necessary?

5.4.2 View Image

How successful is the SAR image in portraying all potentially dangerous icebergs?

How often is it necessary to change the image in the detail window? Would a continuous scroll under the overview window provide an advantage?

Is it necessary to have several different resolutions available for the overview window? If so, which and how many?

Which resolutions are used most in the detail window?

How long does the SAR image remain useful after reception? Which variables affect the useful duration of a flightline image?

Is the message window readable? At what height is the STAR-VUE screen on the bridge relative to eye level standing and seated? Does the terminology in the message window cause irritation/confusion? Would it be better to arrange the buttons in a box at the bottom left-hand corner of the screen and the message window in the bottom right as opposed to the present configuration?

To what extent would the PRINT function be used if it were available with the current system?

Do operators want to position the ship using latitude and longitude or by matching the SAR image with marine radar, or both?

Bearing in mind that the ice moves in relation to the land and the ship in relation to the land and the ice, is it realistic to plot a course on the SAR image more than (for example) two hours after reception? According to Coastguard, the potential for ice movement close to shore and in parts of the Beaufort Sea is such that the relationship between flows can change in as little as ten minutes. In this case, it might be difficult and misleading to draw on the image.

If ANNO ON/OFF is used, would it be misleading to plot the ship's position using latitude and longitude, bearing in mind the above cautions? How accurate can STAR-VUE be with its lat and long grid and for how long after reception is it useful?

5.4.3 View Reception

Is the information in the message window sufficient?

How long after reception is the image incorporated into the system such that it is accessible through the SELECT IMAGE menu?

5.4.4 Controls

How well does the rollerball work? Would there be room to move a mouse around the surface to the left and right of the monitor on the bridge?

Is the labelling on the soft buttons leading to any confusion?

5.4.5 Screens

At what height is the STAR-VUE screen? Is there any problem reading the message window?

How many screens are necessary? Some possibilities include: (1) the present single screen displaying both the overview and detail images plus a second screen for marine radar; (2) three screens, one each for overview, detail, and marine radar; (3) three screens, one for both overview and detail images, one for all textual information, one for marine radar; (4) three screens, with a choice concerning which combinations of images are displayed at any time; and (5) four screens (including the VIEW FAX) on which any desired combination of images could be shown. (Is it necessary for the satellite information to be displayed continuously throughout the voyage?)

5.4.6 Workstation

How serious is the problem of glare from STAR-VUE as it affects night vision? Would a red image be beneficial?

Is it practical/advisable to assign a single operator to the STAR-VUE/NAV-ICE workstation?

Should casual use of STAR-VUE be discouraged?

Will the person using STAR-VUE require direct visual inspection of the ice conditions from the windows? If so, under what conditions and how frequently?

How long is it reasonable to expect vigilant performance from observers of STAR-VUE screens?

What use would be made of documentation, such as a user manual, aboard ship?

5.4.7 STAR-VUE and Marine Radar

Is the orientation of the SAR image on STAR-VUE suitable? For example, will a North arrow be as important as some laboratory subjects indicated?

Would orienting the marine radar to match the SAR image be an attractive option?

Do ship's personnel value coloured SAR or marine radar images?

Would it be very useful for the cumulative distance to be calculated for drawn line segments, thereby enabling the planner to draw several alternative routes and compare distances?

5.4.8 Training, Documentation and Support

The results of the STAR-VUE study yielded a great deal of information on the need for training. Although the basic system is very easy to master, it is clear that this system will provide new data to a very different community of users. Minimum training for users of STAR-VUE will require at least several days (3 to 5) and should include information describing the STAR-VUE system, interpretation of images, and necessary cautions. Topics to be covered would include: (1) the relationship between ice-classification and navigational uses of STAR-VUE; (2) use of the latitude/longitude grid for geo-referencing; and (3) teaching users to match STAR-VUE and marine radar images, which is extremely important.

Ships' operators have a mass of documents available for all the equipment on the bridge and very little time to read it. The less need for recourse to a manual the better.

The user's manual should have a good schematic representation of the menu structure. A 'troubleshooter's' manual may also be necessary.

The need for simulators to improve the training of personnel is also indicated and some progress in this area is described later in this report. It is clear that much more work is required in training, even of professional personnel, in the area of ice interpretation using SAR data.

The question of which resolutions are optimal for interpreting the various ice types has been investigated as follows: for a number of specified ice types, several images will be set up to be displayed, one at a time, to ice experts. For each trial, the name of the ice type will appear on a screen, followed by a SAR image of some ice. The task for the subject is to press a button as soon as he has decided whether or not the image he is looking at was described by the name presented earlier. Reaction times will be compared for different ice types and for different resolutions and for any interaction between the two variables. These results are reported in Chapter 6.

6. EFFICIENCY AND CONFIDENCE OF CLASSIFICATION OF SEA ICE USING CRT-DISPLAYED SAR IMAGERY

6.1 Introduction

STAR-VUE is an instrument designed to present high resolution SAR imagery received in real-time from airborne radar systems. It will be used for ice interpretation by ship's navigators and offshore rig personnel. In order to optimize STAR-VUE'S functions, alternative methods of presenting the imagery to its users are being investigated. The present experiment was designed to examine the efficiency of ice classification as a function of image resolution and/or ice type.

6.2 Method

6.2.1 Subjects

Seven male subjects participated in the study, six of whom were highly experienced at ice interpretation from SAR images. One had some experience but was not considered to be at the expert level. Five, including the latter, were INTERA employees, and two were invited from Gulf to take part. Subjects were tested individually and were not paid for their time.

6.2.2 Task and Apparatus

The task involved responding to each of 125 synthetic aperture radar (SAR) images displayed by way of a DEC PDP 11/73 Processor on a 640 X 480 pixel (40 x 30 centimeters) display. Each image portrayed a view of sea ice and covered most of the screen. On each trial, a question specifying an ice-type was presented on the screen, for example, "Is this old ice? Yes/no?" This was followed by an image and a yellow cursor box. The ice within the box was to be classified. Subjects were to respond by depressing one of two keys labelled "yes/no", and then to rate the confidence of their judgement.

An average of five different images of each of five ice types appeared at five different resolutions, constituting 125 images in all. An employee of INTERA with extensive experience in SAR and ice imagery interpretation was responsible for choosing, classifying and displaying the 125 images for the experiment. The classification system he used (referred to for this report as the "original classification") was from the standard AES Manual[1] of Sea-Ice Reporting (Atmospheric Environment Service, 1980). The manual's description for the "Rubbled/ridged" category was slightly adapted for the purposes of the experiment. A hardcopy textual description of the ice-type classes used was available alongside the apparatus. The ice types represented (see Appendix for descriptions) were:

1. Open water/new ice;
2. Young ice;
3. First-year ice;
4. Old ice; and
5. Rubbled/ridged ice.

Ice types were presented at the following resolutions:

Metres per pixel	image size (kilometres)	cursor box size (kilometres)	image size (pixels)	cursor box size (pixels)
12	5.76 x 5.76	2 x 2	480 x 480	166 x 166
24	11.52 x11.52	4 x 4	480 x 480	166 x 166
48	11.52 x 11.52	4 x 4	240 x 240	83 x 83
96	23.04 x 23.04	8 x 8	240 x 240	83 x 83
192	46.08 x 46.08	16 x16	240 x 240	83 x 83

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(1) Atmospheric Environment Service (1980). MAN-ICE : Manual for Standard Procedures and Practices for Observing and Reporting Sea-Ice Conditions, 5th Edition AES.

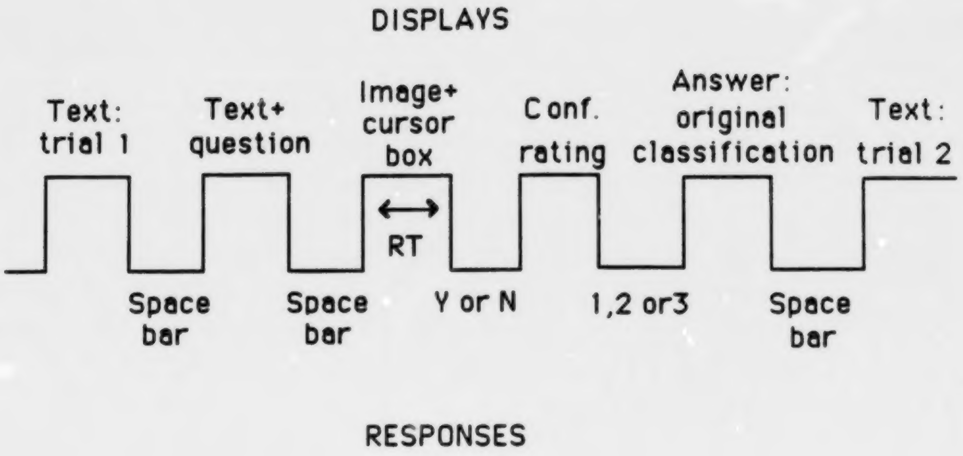
There were five blocks of trials, one for each resolution, presented in a different, random order for each subject. In each block, there were 25 trials, an average of five images of each ice type. The ice types were mixed randomly within the blocks.

A set of ten practice trials of mixed resolutions were run to familiarize subjects with the task. Subjects sat approximately one metre from the screen and responded on a standard keyboard, using the 'f' key labelled 'Y' for a 'yes' response, the 'j' key labelled 'N' for a 'no' response, the 1, 2 and 3 keys on the top left- or right-hand side of the keyboard for confidence level responses and the space bar for moving from trial to trial.

Within each block of trials, the subject was presented with five questions for each ice type. Four of the five questions matched the original classification of the image to follow, while the remaining question was a mismatch, requiring a 'no' response to be in agreement. Thus, 20% of the answers given in the feedback were "no". The image selected for a "no" answer was always taken from a category adjacent to that specified by the question. For example, if a young ice image was shown as part of a "no" trial, the accompanying question would be either, "Is it open water/new ice?" or "Is it first-year ice?".

6.2.3 Procedure and measures

Instructions (see Appendix) were explained by the experimenter using the first practice trial for demonstration. The subject was able to pace the trials himself using the space bar. The sequence of events was as follows:


DISPLAYS
Text: trial 1
Text+ question
Image+ cursor box
RT
Conf. rating
Answer: original classification
Text: trial 2
Space bar
Space bar
Y or N
1,2 or3
Space bar
RESPONSES

Data recorded for each trial:

1. Response Time (RT)
2. Y or N
3. Confidence

On pressing the bar, three lines of textual information appeared on the screen. These indicated the season, the resolution and the geographical area where the image was taken. When ready, the subject pressed the space-bar again to elicit the question. This was in the form. "Is this {ice type X}? Yes/no." When the space bar was again depressed, the text was replaced by the image. Response time was measured from this point until the subject pressed the keys labelled Y or N. Then a confidence rating response of 1, 2 or 3, with 1 indicating a high confidence, was requested. The screen then redisplayed the question and the original classification of the image. Upon pressing the space bar again, the subject was presented with the text for the next trial.

6.3 Results

The data for response time, confidence level ratings and disagreements were subjected to statistical analysis. Comments made during and after the experiment were recorded and later served to aid interpretation of the results and to give some insight into the ice classification process.

6.3.1 Response times

Mean response times are presented in Table 1. An analysis of variance for all seven subjects revealed no significant effects. The last two subjects in the experiment showed markedly different response patterns from the other five subjects. Both were ice experts, one from Gulf and one from INTERA. Their experimental sessions lasted between two and three hours instead of the usual one to two hours. They showed a particular tendency to think and talk about the image while it was being displayed rather than responding prior to discussing the reasons underlying their response. This was reflected in their response times, which ranged from 1.81 to 62.77 seconds for subject 6 and from 2.66 to 81.09 seconds for subject 7. Mean response time over all trials for each subject were as follows:

Subject #	Mean RT in secs
1	6.93
2	6.71
3	7.22
4	6.19
5	3.69
6	10.80
7	17.17

When the response time data for subjects 6 and 7 were removed from the sample, there was a main effect for ice type, $F(4,16) = 4.55$, $p < .05$, as well as an interaction effect for ice type with resolution $F(16,64) = 2.23$, $p < .05$. Mean response times for 5 subjects (N=5) are displayed in Table 2. Figures 4 and 5 show the effects graphically. It can be seen that the significance of both the main effect and the interaction is due largely to the "rubbled/ridged ice" (RRI) category. RRI response times are much longer (Figure 4) than the other classifications, especially at 12 and 24 metres per pixel resolutions (Figure 5).

TABLE 1

Mean Response Time (RT), Confidence Rating (C), and Disagreements (D)

n = 7

Resolution by Ice-Type

		12	24	48	96	192	Means
Open water/ new ice	RT	7.00	11.13	10.00	5.23	8.69	8.41
	C	1.26	1.64	1.63	1.71	1.68	1.58
	D	1.20	1.00	1.20	1.25	3.00	1.50 (21.4%)
Young ice	RT	7.72	8.74	7.20	7.22	9.06	7.99
	C	1.55	1.66	1.57	1.93	2.09	1.76
	D	2.83	2.60	2.50	2.33	2.67	2.59 (36.9%)
First-year ice	RT	11.85	11.91	7.60	7.86	8.30	9.50
	C	1.39	1.67	1.46	2.00	2.20	1.74
	D	1.00	1.67	0.50	1.60	1.00	1.21 (17.3%)
Old ice	RT	7.88	7.18	6.48	5.37	6.53	6.69
	C	1.51	1.29	1.49	1.91	1.66	1.57
	D	1.00	2.00	1.40	1.20	0.80	1.28 (18.3%)
Rubbled/ ridged ice	RT	11.82	11.48	9.73	6.25	7.41	9.34
	C	1.69	1.74	1.49	1.83	1.77	1.70
	D	2.80	1.80	3.00	3.80	3.60	3.00 (42.9%)
Means	RT	9.25	10.09	8.20	6.39	8.00	
	C	1.48	1.60	1.53	1.88	1.88	
	D	1.84	1.84	1.80	2.08	2.20	
		(26.3%)	(26.3%)	(25.7%)	(29.7%)	(31.4%)	

TABLE 2
Mean Response Time: Resolution by Ice-Type
n = 5*

	12	24	48	96	192	Means
Open water/ new ice	4.72	6.59	6.36	4.98	7.68	6.07
Young ice	6.68	5.62	5.42	6.33	8.45	6.50
First-year ice	4.83	5.28	3.84	6.68	6.91	5.54
Old ice	6.01	3.31	4.49	4.46	4.74	4.60
Rubbled/ ridged ice	10.92	9.63	7.25	6.38	5.92	8.02
Means	6.63	6.09	5.47	5.80	6.74	

* Response Times for subjects 6 and 7 excluded.

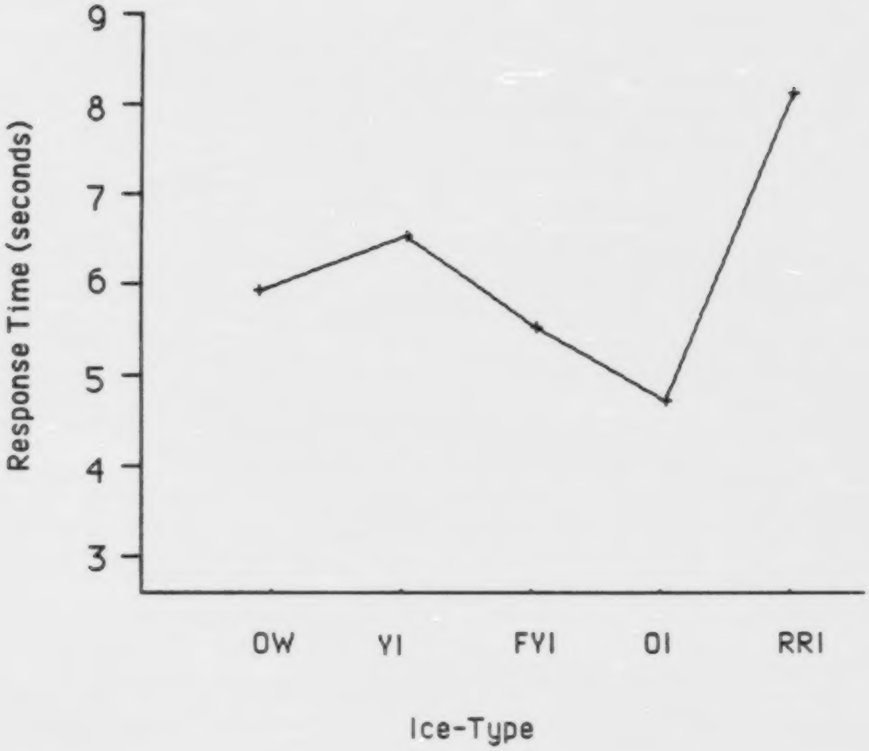


Figure 4 Mean Response Time (seconds): Ice -Type for n=5

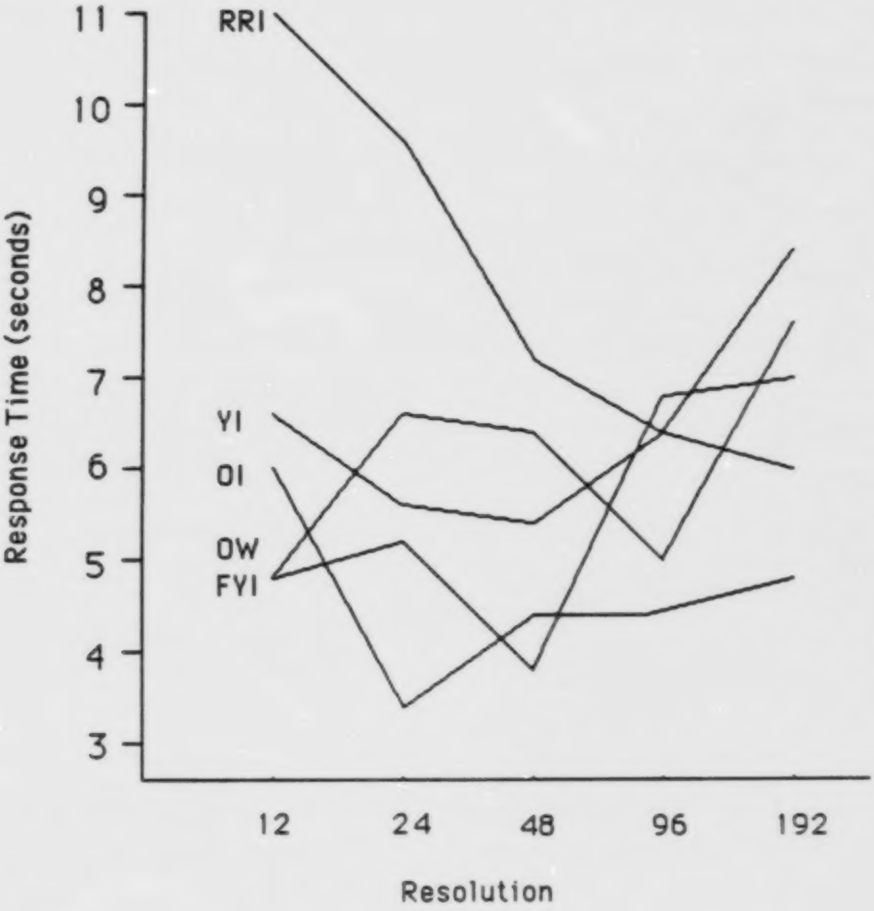


Figure 5 Mean Response Time (seconds) : Resolution by Ice -Type for n=5

6.3.2 Confidence Ratings

Means are displayed in Table 1. An analysis of variance revealed a main effect for resolution, $F(4,24) = 3.31$, $p < .05$, shown graphically in Figure 6. Subjects rated their decisions with less confidence at the two lowest resolutions, 96 and 192 metres per pixel.

6.3.3 Disagreements

Table 3 indicates the number of subjects answering in disagreement with the original classification. Another measure which arose from the comments was the number of alternative categories suggested for each image. These are presented in the square brackets in Table 4.
Mean differences are shown in Table 1. Analysis of variance revealed a main effect for ice-type , $F(4,24) = 8.78$, $p < .001$, shown in Figure 7. More disagreements occurred when the image itself (i.e., regardless of the question) was in the "young ice" and the "rubbled/ridged ice" categories than when it was in any of the other three categories.

6.3.4 Verbal Reports of Subjects

The high frequency of disagreement between the subjects' responses and the original classification prompted subjects to explain why their opinions differed from the presented interpretation. This provided valuable information regarding their approach to the task of ice interpretation and outlined the need for additional information which would have aided them in their decisions and judgements.

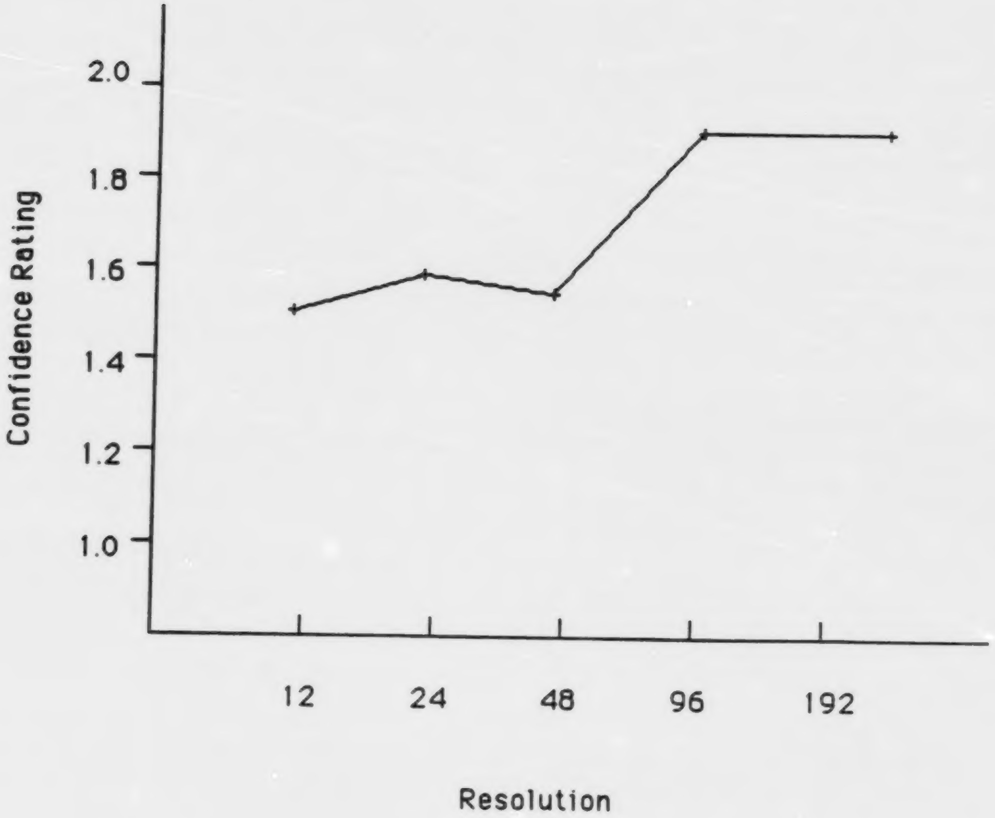


Figure 6 Confidence Rating (1.0-3.0): Resolution

n=7

TABLE 3
Number of subjects disagreeing per image*
(N=7)

Trial #	12	24	48	96	192
1	1	0	1	1	**6**
2	2	2	0	3	0
3	**4**	1	1	**7**	0
4	0	2	0	2	**5**
5	1	**4**	0	**4**	0
6	0	1	2	2	1
7	0	1	0	3	**5**
8	**7**	1	3	0	0
9	3	3	1	3	1
10	**4**	2	2	1	2
11	1	0	0	1	**4**
12	3	1	2	1	**6**
13	**4**	**4**	3	1	3
14	0	2	3	**4**	0
15	2	2	**4**	2	2
16	3	1	2	2	2
17	0	0	1	**5**	1
18	0	**7**	**6**	0	0
19	2	3	0	0	**4**
20	2	1	**4**	1	1
21	1	1	**4**	1	2
22	2	**5**	2	1	1
23	0	0	2	3	0
24	2	2	1	**4**	**4**
25	3	0	1	0	**5**

* Images for which four or more of the seven subjects disagreed with the classification are indicated by bold-faced entries.

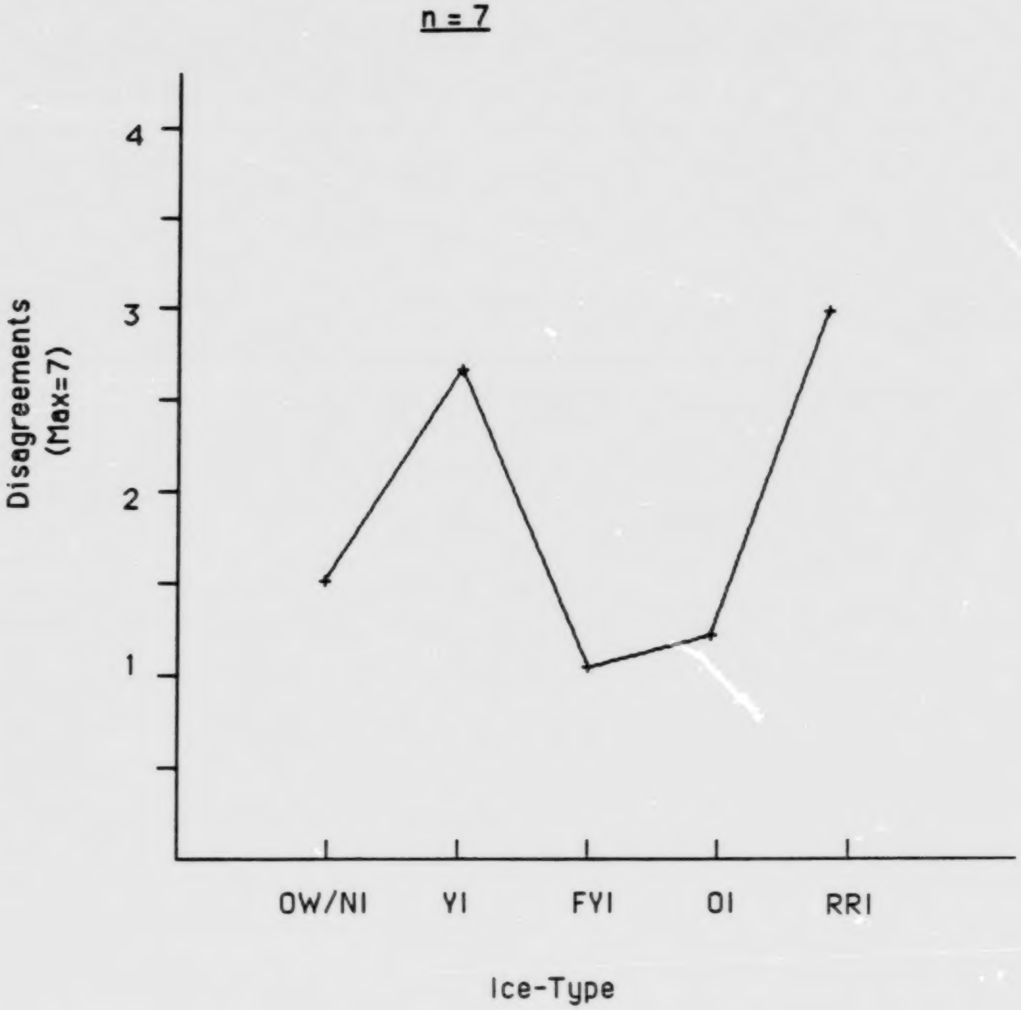


Figure 7 Disagreements: Ice-Type

TABLE 4
Items For Which Three or More Subjects* Disagreed With the Original Classification
n = 7

	12	24	48	96	192	Total no. of items/ ice-type
Open water/ new ice	9(3)[1] 16(3)[1]			2(3)[2]	4(5)[2] 11(4)[1]	5
Young ice	8(7)[1] 10(4)[1] 12(3)[2]	13(4)[1] 19(3)[1] 22(5)[2]	14(3)[1] 15(4)[1] 20(4)[2]	7(3)[2] 17(5)[1]	1(6)[1] 12(6)[1]	13
First-year ice	25(3)[1]	9(3)[2]		5(4)[1]		3
Old ice		18(7)[1]	8(3)[1] 13(3)[1]	9(3)[1]	13(3)[2]	5
Rubbled/ ridged ice	3(4)[1] 13(4)[1]	5(4)[0]	18(6)[1] 21(4)[2]	3(7)[1] 14(4)[2] 23(3)[2] 24(4)[1]	7(5)[2] 19(4)[1] 24(4)[1] 25(5)[1]	13
Total no. of items/ resolution	8	6	7	9	9	

*KEY ___ = Item label, 1 to 25, for each resolution
( ) = Number of subjects disagreeing with that item
[ ] = Number of alternative categories suggested

6.4 Discussion

6.4.1 Response Times

The unexpected range of response times is indicative of the complexity of the interpretation task. Rather than reacting promptly to the question preceeding the image as they were instructed, subjects often appeared to classify the ice in their own terms before comparing their conclusion to the question. They frequently talked about an image, described the ice features, and explained their rationale in choosing a particular ice-type. Particularly during lengthy trials, some subjects forgot the question. Response times ranged from 1.39 seconds to 81.09 seconds.

6.4.1.1 Main effect for ice-type

The significant effect of ice-type on response time revealed by the analysis of variance (see Figure 4) suggests that subjects were thinking longer about and/or discussing images in the "young ice" and particularly the "rubbled/ridged ice" categories than those in the other three. This result coincides with comments from the subjects about the classification system used.

The first three categories, "open water/new ice", "young ice" and "first-year ice", form part of a continuum based on age. They are not always clearly distinguishable on the basis of SAR imagery. For example, two criteria based upon measurement are: new ice is up to 10 cm. thick, young ice 10 to 30 cm and first-year from 30 cm to 2 metres; and, after September 30, ice previously described as young ice is officially classified as first-year ice. These two criteria were not provided to subjects in the present experiment. Furthermore, since young ice is described as the transition between new and first-year ice, these three categories are more closely related to each other than to old ice, which is more easily recognizable by its features (see Ice Class Definitions in the Appendix). Therefore, the difficulty of distinguishing between new and young ice and between young and first-year ice may have led to the longer response times in the young ice category.

The rubbled /ridged ice category prompted a number of comments. In summary, the rubbled/ridged classification is not mutually exclusive from the other categories, particularly old ice. The first four ice-types are defined by age, whereas rubbled/ridged is descriptive. One subject from Gulf pointed out that during ice-classification training, he was taught to first determine the age, secondly the descriptive features. The definition of rubbled/ridged ice was slightly adapted for the experiment. Several subjects disagreed with this adaptation.

6.4.1.2 Interaction: ice-type by resolution

The rubbled/ridged category displayed a markedly different pattern of response times than the other four ice types (see Figure 5). The first four categories all showed some increase in response times at the lowest resolution, 192 meters per pixel. At this resolution, it took slightly longer to determine either which part of the image was intended for classification or which ice type was present, or both. The rubbled/ridged ice, however, showed significantly longer response times at the highest resolutions of 12 and 24 metres per pixel. When the image could be seen clearly, subjects' decision time was greater for the rubbled/ridged category than for all other classifications and resolutions. It is possible that rubbled/ ridged features may be more difficult to discriminate from a large scale, high resolution picture, because ridge size may appear unnaturally large for that categorization, and/or that loss of surrounding area (context) for high resolutions affects rubbled/ridged ice identification more than for the classification of other ice-types. This suggests that several different resolutions of SAR imagery may need to be available to enable optimal interpretation of all ice types. Figure 6 suggests, for example, that old ice is most quickly identified at 24 metres per pixel, whereas rubbled/ridged is most quickly identified at 192 metres per pixel. A high resolution image (e.g.,12 metres per pixel) may provide textural information which is absent in the lower resolutions but at the expense of losing certain geometrical or contextual information about the ice in the surrounding area.

6.4.2 Confidence Rating

The analysis of variance revealed (see Figure 6) that the lower resolutions, 96 and 192 metres per pixel, did coincide with lower confidence for classification decisions. This finding may reflect the influence of two factors. More than one ice type sometimes appeared in the cursor box at these resolutions, and although subjects were instructed to identify the central portion or the predominant type, their comments indicated that they were not always certain which part of the image should command their focal attention. Secondly, lack of detail disallowed accurate perception of some salient features.

6.4.3 Disagreements

The large number and variety of disagreements among the subjects were unexpected. In three cases (see Table 3), disagreement with the original classification was unanimous. However, even more revealing is the finding that between 2 and 5 subjects disagreed with the original classification for many items. This result implies that there may be more variation in ice classification from SAR data than is generally acknowledged. Also, in several cases (see Table 4, square brackets), the original classification and two alternative categorizations were expressed, indicating that some of the images were assigned to three different categories out of five possible categories, suggesting that all ice experts may not employ the same concepts or dimensions to determine ice-type.

Results of the analysis of variance for disagreements (see Figure 7) show a pattern similar to but even more pronounced than the ice-type effect on response time (Figure 4). The "young ice" and "rubbled/ridged ice" categories prompted a greater proportion of disagreements than the other three. Problems with these categories, as seen from the subjects' comments, have already been discussed and are most likely to have led to this highly significant effect of ice type on the frequency of disagreement.

6.4.4 Verbal reports of subjects

Comments made by the subjects during and after the experiment served as aids both to explaining results and to providing insights into the mental processes by which ice experts classify ice from SAR imagery. Comments also served to identify some of the necessary refinements in conducting a future set of experiments:

1) The defining characteristics of the rubbled/ridged category require refinement and/or alteration.

2) More information should be given regarding the exact dates of images, the geographical area, depth of the water, a picture of the context surrounding the image to be classified (perhaps by a low resolution swath as on the STAR-VUE screen), and the past climate and wind conditions in the area.

3) A response panel separate from the standard keyboard should be used rather than selected keys from the standard keyboard.

4) Feedback should not imply that subjects are in error when they disagree with the experimental classification of images.

5) An arrow on the images to indicate precisely the area of ice to be classified would eliminate unnecessary uncertainty.

6) The question should remain on the screen when the image is presented so that subjects are not in danger of forgetting the question as they study the image.

Overall, the initial results of this study suggest the following questions for further investigation:

1) The effect of providing contextual information, e.g., the area surrounding the cursor box, at a lower resolution (such as on the overview window of STAR-VUE) should be assessed in future experiments.

2) How much contextual imagery should surround or accompany an area of ice to be identified?

3) How can ice-types be defined to lead to consensus in judgement by ice experts?

4) What information should accompany SAR imagery to ensure categorical judgements about ice-type can be made as efficiently as the

image quality will allow?

5) Which resolutions are optimal for the identification of each ice type?

6) With a view toward designing an expert system for ice classification and as a navigational aid, which SAR image features are salient and what are the relative salience weightings across features?

7.0 SIMULATOR STUDIES

The studies outlined in the previous sections of this report have indicated that there is a need to train personnel in the use of STAR-VUE. The STAR-VUE system is relatively easy to use and we do not anticipate any problems if users are given a short introductory course. Our studies have shown, however, that there is a much more fundamental need to train personnel in the classification of sea ice using SAR data. The problems associated with learning how to use SAR and marine radar data together also have to be addressed.

The study that was described in Chapter 6 used the STAR-VUE host computer to display a number of selected SAR images of different ice types at a number of different resolutions. The system was used primarily to answer specific questions about interpreting ice with SAR data displayed at these different resolutions. Used in this way, however, the STAR-VUE system could also be programmed to teach users about ice classification with the appropriate choice of imagery.

STAR-VUE has all the functionality required for use as a training simulator, since both text and data can be displayed on the same video display. A training tape containing samples of imagery could easily be prepared in advance by a team of experts and loaded onto the system. The main effort in developing such a program would be in the actual collection and preparation of the image data base. Once this image data base is established, it would be an easy matter to put it on an even cheaper delivery system, perhaps a commercial video disk-based product.

The problem of teaching personnel to use STAR-VUE in an actual shipboard environment must also be discussed. From our experience with Canarctic, it is clear that STAR-VUE functions as an integral part of the ship's ice reconnaissance system. Any training program must recognize that the information that is available from other sensors such as satellites, marine radars, etc., and the available meterological data, help to make up a complete picture of the ice conditions in the vicinity of the vessel. A complete training simulator, therefore, must not only use SAR data, but must also make use of the other information that is available to the navigator.

One of the limitations on the use of SAR or SLAR for tactical support or hazard avoidance is that it can provide only one or possibly two snapshots per day in the high Arctic because of the distances between airports. As the ship advances through the ice cover, it is vital that its location relative to the imagery be known. This can be done by comparing the imagery to the marine radar display. Standard radar PPI displays are not well suited to this tracking requirement both because they must be viewed in relative darkness and because it is difficult to freeze the image for detailed analysis.

The early research conducted by INTERA for TDC showed the need for a bright display of the marine radar. A number of commercial repeater display systems have been evaluated for this role and a recently available scan converter produced by Folsom Research Inc. has been integrated into the STAR-VUE system. Thus, both SAR and marine radar can be displayed on two video monitors controlled by the same user interface.

The task of tracking the ship's progress on the SAR display using the marine radar is very complex. It involves, among other tasks, pattern recognition, comparison, memory and image rotation.

The need to develop systems to train personnel to perform this image correlation function is obvious to those who have had to learn this under severe Arctic conditions. With this training in mind, INTERA has developed systems to display both SAR and marine radar data using a single display screen. In addition, it has been shown that marine radar data can be simulated from SAR data. This makes it possible to design new types of simulators.

7.1 Image Display System (IDS)

IDS is an image display system designed to allow users to display and manipulate digital SAR and marine radar images. The system was written to run on a 68000 based supermicro computer (MASSCOMP MC 500) with a high resolution graphics display screen (832 x 600 pixels).

Both STAR-1 SAR and marine radar data collected by INTERA's RIDS system can be displayed by this system. Images can be viewed individually or together using a split screen.

By using the system in split screen mode, users can scroll through the SAR and marine radar data collected in a given area. Thus, it is possible to retrace the path taken by a ship such as the M.V. Arctic in the ice. The data displayed are identical to those received on the ship, so it is possible to simulate actual bridge conditions with such a system.

IDS also assists users in matching RIDS and SAR images by allowing the user to extract regions of the SAR image and display them at the same scale as the marine radar. Other useful features include image rotation and colour assignment. A typical IDS display screen showing SAR and marine radar data is shown in Figure 8. A user's manual for IDS is included in the appendices.

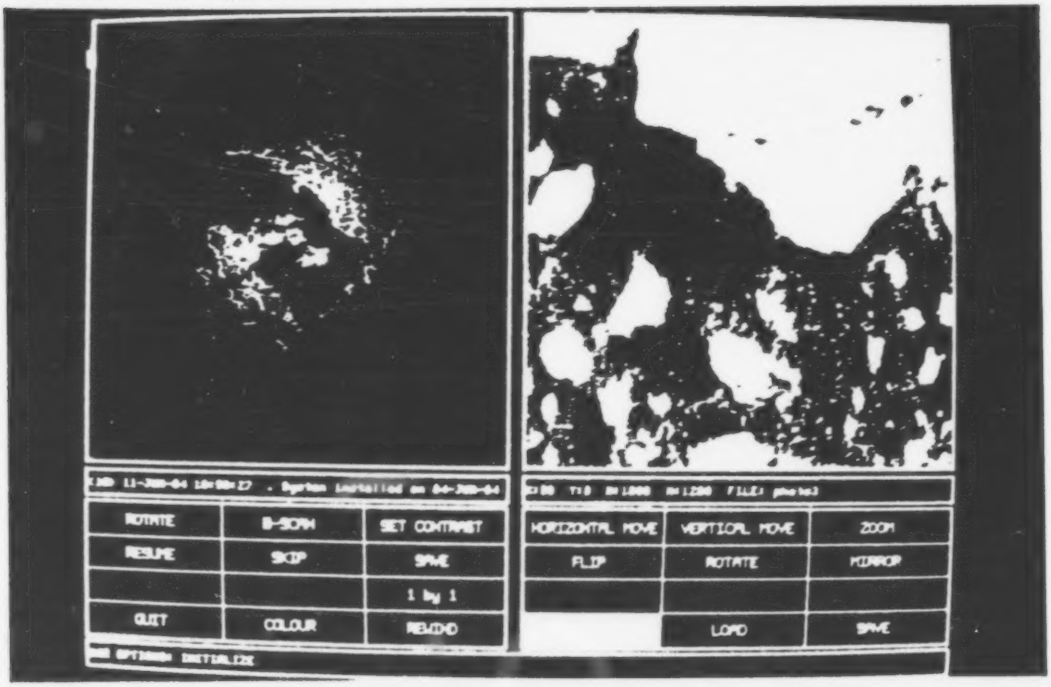

ROTATE
B-SCAN
SET CONTRAST
RESUME
SKIP
SAVE
1 by 1
QUIT
COLOUR
REWIND
HORIZONTAL MOVE
VERTICAL MOVE
ZOOM
FLIP
ROTATE
MIRROR
LOAD
SAVE

Figure 8 Typical IDS Display of RIDS and SAR Data From the Same Operational Area

7.2 Simulation of Marine Radar Returns From SAR Data

7.2.1 Introduction

The IDS system allows the user to display SAR and marine radar data that have been collected in the field. It is therefore very useful for simulating the actual conditions that existed on a ship when these data were collected. The primary limitation of this system, however, is that it is able to display the marine radar only in the area where the ship actually went. Its data base is accordingly very limited.

A complete simulator should allow users the option of choosing any path through the large area ice map provided by the airborne SAR. Thus, a system that would allow users this flexibility is very desirable.
It is possible to construct such a system if the corresponding marine radar imagery can be generated from the SAR data. This chapter therefore summarizes our attempts to generate marine radar imagery from airborne SAR to construct such a simulator.

This is a very difficult problem because of the differences in antenna heights (10,000 m for aircraft and 30 m for marine), differences in antenna gain and differences in signal processing between the marine radar and the SAR. Targets generally look very different when detected with these two systems.

7.2.2 Background

In microwave remote sensing, sea ice is usually divided into first-year (FY) and multi-year (MY) types. One of their major differences is the brine content within the ice. Multi-year ice has much lower salinity than first-year ice, having had the brine dissipate during summer melt season. Deformation of FY and MY ices also happens from the action of wind, ocean currents, waves and pressure. Pressure may cause sheets of ice to pile up in ridges above and below the waterline. A new pressure ridge, usually consisting of broken fragments of ice, has a steep side slope exceeding 40 degrees, whereas weathered (notably MY) ridges are more rounded and have a more gentle slope.

The radar signal return is a strong function of the radar cross section of the target, the latter in turn being determined by the target's dielectric properties.

The high salinity of FY ice always ensures a very small signal penetration, and essentially all of the signal return is from surface scattering. In winter, the smooth FY ice surface causes reflection in the specular direction, and most energy is directed away from the radar. The backscattering coefficient of FY ice is therefore understandably small in winter.

The surface scattering pattern on rough MY ice surfaces, on the other hand, consists mainly of a diffused component, which gives a higher radar return than does smooth FY ice. In addition, the low salinity and the inclusions of air pockets in MY ice allow radar waves to penetrate to a great depth, and as a result, volume scattering takes place. At high frequencies, the volume scattering is much larger than the surface scattering.

In the summer, however, this situation can be quite different. When the rough superimposed surface of FY ice is exposed, and, at the same time, melt water of MY ice attenuates the signal penetrating into the volume-scattering region, the return of the FY ice becomes the same as or even higher than that of the MY ice. The contrast generally returns to its normal order during the winter months.

Thus, we can see that radar remote sensing of sea ice is a very complicated phenomena and is determined to a large extent by the physical properties of the ice itself. In addition, the radar returns are also complicated by such factors as:

1. Ground plane interference - When the antenna and target are near the earth surface, interference effects can be caused by a phase difference between the direct and reflected waves;

2. Refraction - The decrease in refractive index with altitude means that the velocity of propagation increases with altitude, causing radar waves to bend downward; and

3. Effects of the earth's curvature - Radar reflectivity is affected by the curvature of the earth. The earth's curvature can cause the amplitude of the reflected waves to be decreased.

7.2.3 Simulation of marine radar from SAR

The SAR has been described as a side-looking radar with the antenna directed perpendicular to the path of the vehicle carrying the radar. The airborne SAR generates an image of the illuminated area which parallels the flight line of the aircraft. The SAR image is thus presented in XY rectangular coordinates. This differs from a surface-based marine radar, which scans targets in an angular direction and therefore generates row formatted data. Secondly, the received SAR signal does not appear to have a strong dependency on range.

With this picture in mind, it is easily seen that the simulation of marine data from SAR should consist of the following tasks:

(1) scan conversion - XY coordinated SAR data are transformed to R, theta marine space; and
(2) Dependence of R must be introduced into the SAR in order to compensate for the range dependent gain of a marine radar.

(1) Scan conversion

Resolution cells (pixels) of SAR and marine radars are of different size-- for example, 24m by 24m or 12m by 12m for SAR, and perhaps 0.7 degrees azimuth width and 37.5 m radial length for marine. The relative density of the two types of cells also varies with range; at far range, for example, one marine radar cell contains a large number of SAR cells. The scan transformation is further complicated along cell boundaries where one SAR pixel belongs to two or more marine cells, causing the inclusion of the pixel to be ambiguous. In most cases, the pixel can be excluded in computations. Given a SAR image f(x,y) at any full size pixel (x,y) inside the marine radar cell, the gray level of the marine cell can be approximated by some smoothed form of f(x,y), g(x,y), where g(x,y) is obtained by one of the following schemes:

1. Nearest neighborhood averaging - The smoothed image g(x,y) is obtained by averaging the gray levels of the pixels of f contained in nearest neighborhood of (x,y);

2. Overall averaging - Denoting the set of full-size pixels in the marine cell as S, g(x,y) is obtained by averaging f(x,y) for all (x,y) in S; or

3. Peak value approximation - g(x,y) is assigned the maximum value of f(x,y) in S, where S is defined as in 2.

Again, g(x,y) is constant in the whole marine cell.

The smoothed image g(x,y) is then transformed into polar marine space (r, theta) by:

$r = (x2 + y2)1/2$
$\text{theta} = \tan\text{-}1\ (y/x)$

All of the above three schemes have the effect of smoothing out pixel intensities within the cell, though some contrast may also be lost.

(2) Range Dependency

The range independency of the SAR radar equation has to be compensated if a SAR-simulated marine image is desired. The required range correction factor depends on sea ice types and their corresponding backscattering coefficients. To simplify the analysis, a sea ice picture composed of pressure ridges and flat FY & MY ices in open water can be assumed. This represents only what might be typical of "average" conditions. It does not take into account the different backscattering characteristics of FY & MY ices, nor is the sampling season (summer or winter) specified.

If the target ridge is beamfilling in azimuth, then the equation for flat ice (1/R3) will apply as the effective area of the feature is a function of range. If, however, the feature is of limited horizontal extent, then the point target model will apply and the 1/R4 remains valid. We assume here that the ridges are effectively beamfilling most of the time. A secondary effect may also apply to ridges which stick up out of the general ice sheet.

SAR to marine simulator

Using these theories, the simulation can then be easily carried out. The SAR data, which are now in R, theta radar space, are categorized according to the simplified model into three areas of interests: open water, flat ice surface, and pressure ridge. This is done by filtering the data with respect to thresholding values t1, t2 corresponding to the three areas' gray levels, which may be approximated from the histogram of the image. Finally, the thresholded data are multiplied by a correction function Mi(R, theta) , where Mi(R,theta) (i=1,2,3 corresponding to the three ice features mentioned earlier) and the backscattering features of targets. In summary, Mi(R, theta) takes the following forms:

(i) M1(R, theta) = 0 for open water, 0<t<t1 ;

(ii) M2(R,theta) = A cos2 theta /R3 for flat surface scatterer, t1<t<t2, where A is some constant; and

(iii) M3(R,theta) = B/R2 for pressure ridges, t2<t<255, where B is again a constant to be determined.

7.2.4 Results and discussion

Two data sets have been used in this study of the simulation problem. One of them contains SAR imagery flown in support of CIDS in the Western

Beaufort in the Winter of 1984. The other set consists of imagery taken over the High Arctic during the voyage of M.V. Arctic in June 1984. Several marine radar and SAR image pairs of the same operational area in these two data sets were available for comparisons with simulated images.

The radar ranges used in the simulator were 12 nm and 3 nm for CIDS and M.V. Arctic data respectively. The SAR pixel size was 24 x 24 m2 for CIDS and 12 x 12 m2 for M.V. Arctic. The antenna height was assumed to be 30 m, and the azimuth beam width was 0.7 degrees in both cases.

Range dependent factor: In general, the sea ice surface which is composed of both point and surface scatterers could be assumed to have a range dependency of R-4 or R-3. To further complicate the problem, the assumption of near normal incidence ridge surface results in an R-2 relation. This range power ambiguity was studied by observing various combinations of range power. In general, the combination of M2 R-3 and M3 R-2 appears to work reasonably well (Fig. 9 and Fig. 10).

Threshold values: The classification of sea ice features is determined by the threshold values t1 and t2. Correct applications of the function Mi(R, theta) thus relies on the accuracy of selecting t1 and t2.

Multiplication factors: The role of the constants A & B of M2(R, theta) & M3(R, theta) on the image appearance was also studied. A high value of the multiplication factor is not recommended if the area of interest is at close range.

Peak value or averaging approximation: It was mentioned earlier that the marine radar cell at far range could be approximated from SAR pixels by either neighborhood averaging, overall averaging, or peak value approximation. Studies were made on the last two schemes and the discrepancy was in general very minimal between the two.

In summary, the combination of M2 R-3, M3 R-2 using t1=10, 40<t2<60 with 3< A or B <5 and peak value approximation appears to work reasonably

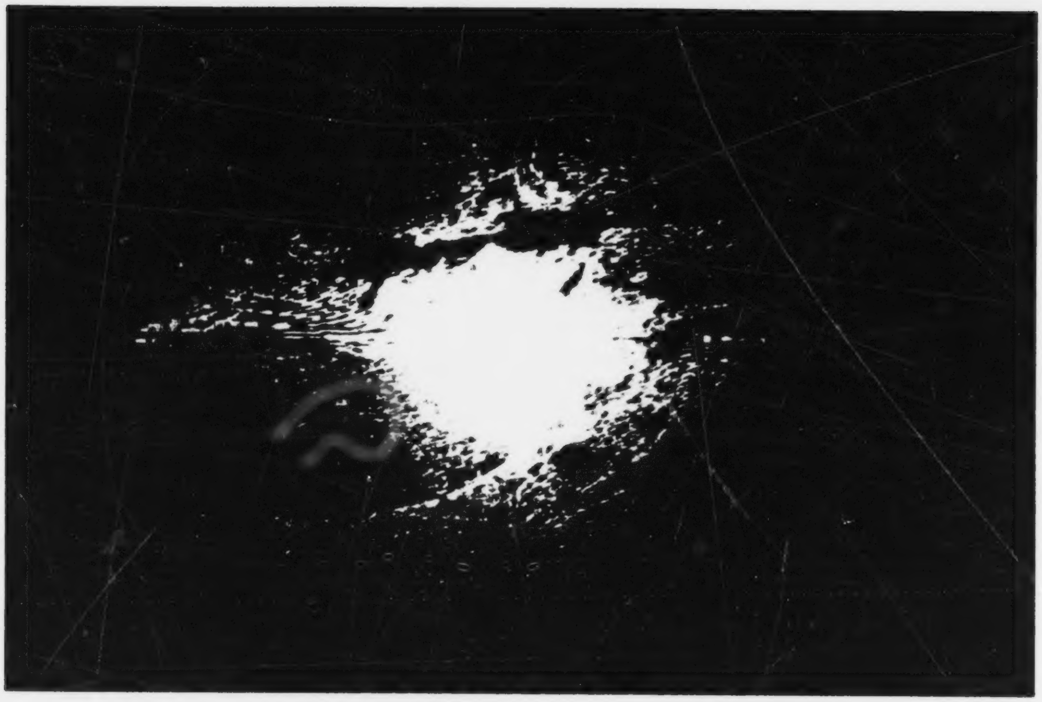


FIGURE 9 Simulated marine radar image of ice conditions around drilling rig. Thresho values t1=10, t2 = 20, correction functions M2= cos 2 theta R-1, M3=R-1 Note that the real SAR and marine radar images are shown in figs 11&12.

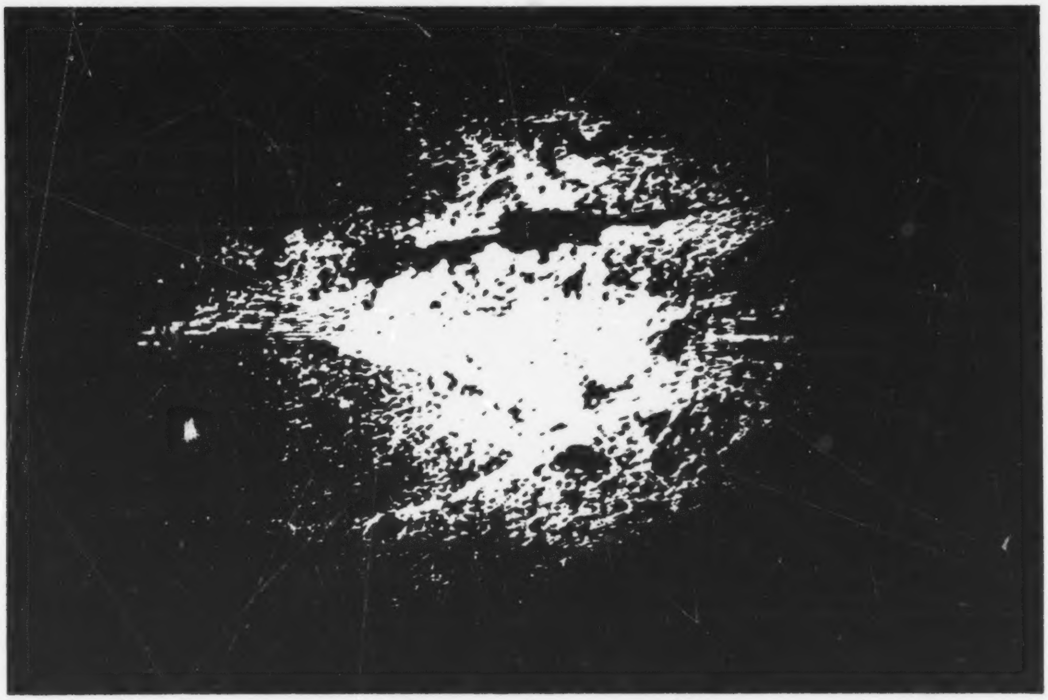


FIGURE 10 Simulated marine radar image of ice conditions around drilling rig. Thresh values t1=10, t2 = 60, correction functions M2= 5cos 2 theta R-3, M3=5R-2.

well in most cases.

Comparisons with real marine images: Several simulated marine radar images were produced as illustrated in Figures 11 and 12. The original SAR images are also included for comparison.

The simulator presented above is based on a simplified sea ice model in which no exact distinction is made between FY and MY ice types. For more rigorous analysis, different backscattering features of each ice type should be included. In such cases, the constant term B and the A.cos^2 theta term of M3 and M2 would be replaced by some more complicated incident-angle dependent functions.

Because of its much higher antenna height, airborne SAR detects much better small surface features than does a surface-based marine radar. In most cases, a marine radar often generates an "edge-map" of the target. It is therefore recommended that the future SAR-simulated marine image, after the range dependency corrections, be edge-enhanced by applying a gradient operator or other edge enhancement techniques so that the final image would bear the closest resemblance to the real marine image.

Conclusion

The complicated backscattering mechanisms between first-year and multi-year ices have made the prediction of radar returns difficult. Based on a simplified sea ice model, though, the use of the airborne SAR data to simulate marine radar images was found to be very encouraging and resulted in useful images. Neglecting the ground plane interference and other effects of the earth, it was observed that the range dependencies for flat ice surface and pressure ridge varied, according to the theory, approximately as R-3 and R-2 respectively.

The next step in this research would be to incorporate these techniques into a working simulator system such that the operator could choose any path through the SAR image and see the corresponding marine radar picture.

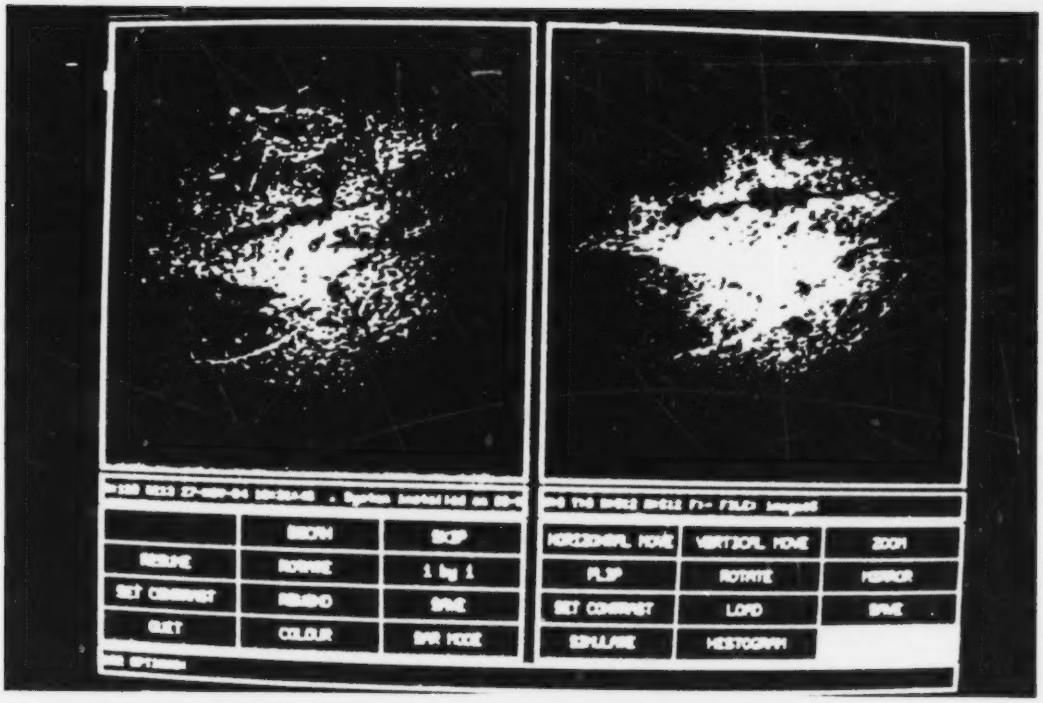

BSCAN
SKIP
RESUME
ROTATE
1 by 1
SET CONTRAST
REWIND
SAVE
QUIT
COLOUR
SAR MODE
HORIZONTAL MOVE
VERTICAL MOVE
ZOOM
FLIP
ROTATE
MIRROR
SET CONTRAST
LOAD
SAVE
SIMULATE
HISTOGRAM

FIGURE 11 Comparison between the simulated marine radar image of figure 10 (right) and the real marine radar image from this area around drillship (left).

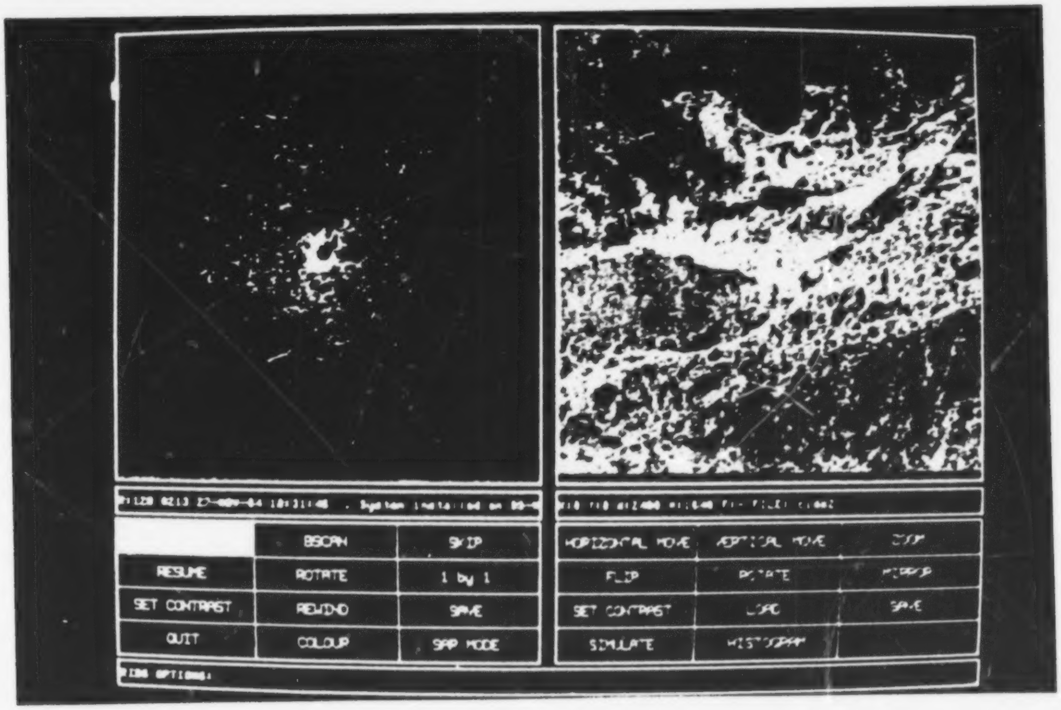

BSCAN
SKIP
RESUME
ROTATE
1 by 1
SET CONTRAST
REWIND
SAVE
QUIT
COLOUR
SAR MODE
HORIZONTAL MOVE
VERTICAL MOVE
ZOOM
FLIP
ROTATE
MIRROR
SET CONTRAST
LOAD
SAVE
SIMULATE
HISTOGRAM

FIGURE 12 Comparison between the real marine radar image of figure 10 (left) and the SAR image from this area around drillship (right)..

8. CONCLUSION AND RECOMMENDATIONS

The majority of the work that has been performed under this project was concerned with the ergonomics of the STAR-VUE system. The early focus on users and tasks, empirical measurement of usage, and an iterative design philosophy has resulted in STAR-VUE being a very easy to use system. An iterative design philosophy may seem expensive since it involves modification, testing, and modification again and again, but with the present state of our understanding about user interface design, it is the only way to ensure excellent systems. We believe that if other systems were designed in this way, they would receive much higher usability marks.

Most of the recommendations that have been made by the human factors group were implemented into the STAR-VUE system. This has resulted in STAR-VUE being a far superior product and one we feel confident will meet the needs of the marine personnel required to use it.

The second part of this program examined the question of ice classification and interpretation using airborne SAR data. It was clear from this study that much more work is needed in this area. One of the major points that can be made concerns our use of a classification scheme that is based on visual observation. With this scheme, much emphasis is placed on the classification of sea ice during its early stage of development.

This causes many problems when we attempt to classify ice with a radar like STAR-1 that has been opimized to enhance the contrast between old and other ice types. It may be that this classification scheme needs to be revised, particularly if radar becomes the primary sensor for ice navigation. It should be remembered that what is important to navigating ships is a knowledge of the ice hazards en route.

The effect of resolution on reaction time is also very interesting. The rubble class seems to get less confusing as the resolution gets coarser. The apparent dip in reaction time for YI, FYI, and OI classes at modest resolutions, we suspect, represents the difference between context and content. Future training simulators should present SAR data to users as is done on the STAR-VUE system, with an overview (context) and high resolution (content) window.

This study also revealed the utility of using a system like STAR-VUE as a training simulator. Although STAR-VUE is an ideal host for such a system, it may be more cost effective to port the assembled SAR data to a much less expensive delivery system for training purposes.

Our study of the problem of developing a training simulator making use of both the SAR and the marine radar has shown us that it is possible to simulate the marine radar data from the SAR. Further work in this area would lead to the development of a complete shipboard training simulator.

11.0 ANNOTATED BIBLIOGRAPHY

Artificial Intelligence

Anderson, G. Leigh (1976) "Image Restoration Based on a Subjective Criterion" IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC - 6 No. 12, December, 1976.

The problem of removing random noise from gray tone images without significantly sacrificing the subjective resolution is considered. Based on a subjective visibility function, which gives the relationship between the visibility of a unit noise and a measure of local spatial detail (spatial masking), two procedures are developed to adapt continuously the finite impulse response of a two-dimensional, noncausal, linear digital filter. At sharp transitions in the image intensity, the filter operator is strongly peaked to preserve the resolution, whereas in flat areas it is flat to effectively average out the random noise. The first procedure (s-filter) is computationally more efficient, but does not perform as well as the second method (sd-filter) which requires solution of a new optimization problem at every picture element. Results of several simulations are presented to demonstrate the feasibility of our approach. Extensions are pointed out to incorporate different adaption procedures and psychovisual criteria other than the type of spatial masking used here.

Badre, Albert N. (1982) "Selecting and Representing Information Structures For Visual Presentation" IEEE Transactions on Systems, Man and Cybernetics Vol. SMC - 12, No. 4.

The objective of this research was to identify and apply experimental techniques for locating and evaluating data patterns and informational "chunks" which are meaningful to the tactical decisionmaker in this decisionmaking tasks. The identification of meaningful chunks of information is useful in specifying criteria for the development of decision-aiding algorithms that search for, classify, and display information. Two main tasks were used for collecting data about informational chunks; reconstruction and copying. ... Participants were 12 military officers, experts; and 12 students, novices to the battle field task. ...In general, the experts' performance was superior to that of the novices on accuracy of reconstruction both for structured scenarios representing likely tactical situations and unstructured scenarios representing situations unlikely to occur on a real battlefild. Both the IPT and sequential techniques revealed that the experts' chunks were tactically meaningful with high frequency, while the novices' chunks were not. The basic element of a chunk for the expert was the tactical relation between two or more tactical units rather than the unit itself. However, even the novice chunked by relating symbols in some meaningful way. There seems to be a direct relationship between the relational density of a chunk and the speed with which the information is processed. Chunk size in terms of relations was found to be related to time given for studying the tactical situation, irrespective of expertise.

Boreham, Dominic, Ernest Edwards (1982) "Extracting Shapes from Grey-Scale Images" International Journal of Man-Machine Studies, 16, 315.

The present work is concerned with grey-scale raster images having more than one bit per pixel, and is an extension, both practically and conceptually, of the earlier work. The transition to grey-scale images introduces a number of problems relating to the structure of images, or more precisely, the structure which the user perceives in the image. Our basic operation on an unstructured grey-scale image is EXTRACT. It corresponds to SAVE, but is more complex both in operation and function. Yhe purpose of the EXTRACT routine is to enable the computer to identify an unstructured shape which the user perceives on the raster screen and which he points to by placing a cursor within it. A shape cannot be identified by the computer merely in terms of a standard analysis of grey-tones appearing in the image on the screen. The separation of the shape from its background is a function of the user's perception, which we will see involves image structuring criteria, sometimes of considerable complexity. In most cases we are dealing not with the physical image on the screen, but with the user's percept, which is an interpretation of the screen image.

Ventresca, James, Ted McCracken, Frank Mores, (1984) "The Design and Development of a Human Interface Automaton" in Proceedings of th 5th Annual Conference & Exposition, Vol II - Technical Sessions, National Computer Graphics Assoc.

This research project culminated in the construction of a super-intelligent computer/human interface for the process control environment. The purpose was to explore the concept of a Human Interface Automaton (HIA) which understands user interface tasks and how to perform them, eg., define page, assign button, update variable, etc. The HIA incorporates a wide range of interactive modalities, eg., high-resolution color graphics, touch, voice, etc. Although the HIA provides for highly customized user interfaces for system applications, it is independent of applicaitons and connects through a well-defined channel. At run time, the HIA is given instructions which define its operation and data transactions. Some application examples were used to test the feasibility of the concept with a minicomputer simulating the host system. The HIA provides a test-bed system for new user interface concepts.

Cognitive

Allen, Robert B. (1982) "Cognitive Factors in Human Interaction with Computers" in Badre, A. and B. Shniedeman (eds.) Directions in Human/Computer Interaction, Chapt. 1 Ablex Publishing Corp.

Designing computer interfaces to match human cognitive processes is increasingly important as computer systems become more sophisticated. This paper examines experimental results, models, and research strategies relevant to cognitive processes in user interfaces for topics including query languages, command languages, programming, problem solving, editing, and displays.

Badre, A. & Shneiderman, Ben (eds.) (1982) Directions in Human/Computer Interaction, Ablex Publishing Corporation.

Benbasat, Izak & Ronald N. Taylor, (1982) "Behavioral Aspects of Information Processing for the Design of Management Information Systems" IEEE Transactions of Systems, Man and Cybernetics, Vol. SMC - 12, July/Aug. 1982.

A computer-based management information system consists of two major components: the machine and the human user. The designers of these systems often do not consider the capabilities and inadequacies of the human component. As a consequence, the computer with its vast information processing abilities tends to overload the human user. This leads to a waste of computing resources and interferes with the proper functioning of the human element. Various models of human information processing behavior are discussed to provide some suggestions for information system design. The topics covered include human abilities to integrate information and judge probabilistic information accurately, the factors which cause information overload, and individual differences in information handling abilities.

Boreham, Dominic, Ernest Edwards (1982) "Extracting Shapes from Grey-Scale Images" International Journal of Man-Machine Studies, 16, 315.

The present work is concerned with grey-scale raster images having more than one bit per pixel, and is an extension, both practically and conceptually, of the earlier work. The transition to grey-scale images introduces a number of problems relating to the structure of images, or more precisely, the structure which the user perceives in the image.
Our basic operation on an unstructured grey-scale image is EXTRACT. It corresponds to SAVE, but is more complex both in operation and function. Yhe purpose of the EXTRACT routine is to enable the computer to identify an unstructured shape which the user perceives on the raster screen and which he points to by placing a cursor within it. A shape cannot be identified by the computer merely in terms of a standard analysis of grey-tones appearing in the image on the screen. The separation of the shape from its background is a function of the user's perception, which we will see involves image structuring criteria, sometimes of considerable complexity. In most cases we are dealing not with the physical image on the screen, but with the user's percept, which is an interpretation of the screen image.

Carey, Tom (1982) "User Differences in Interface Design" Computer Vol. 15, No. 11, Nov. 1982 p. 14 - 20.

The information systems profession has come to appreciate the importance of interactive interfaces that are tailored to distinct user characteristics. One measure of that progress is reflected in the content of recruitment ads for systems professionals. Only in recent years have employers requested "user interface designers" with expertise in the "personalization of features in order to suport a wide variety of user classes (casual to sophisticated) and the use of analogies to users'

existing environment."1 The implied single dimension of users--"casual to sophnisticated" -- is no doubt an ad writer's simplification of a more complex mode. Software designers now recognize several dimensions in specifying user types for any information system, although they are still exploring the nature and interaction of those dimensions.
... In evaluating user characteristics, we will consider three areas: 1) differences in the nature of the task to be performed and the associated mental task model, 2) differences in the nature and extent of the user's cognitive model of the information system, and 3) differences in the nature and extent of the user's exposure to the system. Obviously, the user's exposure to the system interacts with the first two, but only additional effects that are not clearly related to the other areas are considered part of user exposure.

Green, T.R. G., S. J. Payne (1983) The Psychology of Computer Use, Academic Press, Inc., Orlando, Florida.

Guedj, Richard A., Paul J. W. ten Hagen, F. Robert A. Hopgood, Hugh A. Tucker, David A. Duce, (1980) Methodology of Interaction, North-Holland Publishing Co., Amsterdam, New York.

Heiman, Bruce A. (1983) "Cognitive Human Factors" Computer Graphics World (USA), Stanford University, Palo Alto, CA, June 1983.

Many elements must be synthesized into a computer graphics system before it can be considered "user-friendly". Human factors engineering, utility, speed, and cognitive human factors design are the well established dimensions that comprise this friendliness. Human factors engineering, currently a driving force in the computer graphics hardware industry, is associated largely with elements of the physical realm. For example, is the key board at the right height? Does eyestrain ensue from protracted viewing of the monitor? Does the joystick fit into the set of all possible users hands? In Europe, they even have laws that allow into the market place only those machines that achieve certain ergonometric standards.

Utility, on the other hand, is more a matter of truth in advertising. In other words, does the machine perform as promised? This question, in turn, leads to others concerning susceptibility to breakdown and degree of serviceability. Whether the machine can perform it function at a satisfactory speed has long been a dimension of paramount importance. In the past, knowledge of utility, human factors, and speed has constituted sufficient information upon which to base a buying decision. Although people may find computer systems that satisfy them in all these respects, they are soon apt to become unhappy with their new tools. This is because machines are sometimes horribly frustrating for humans to interact with.

Johnson-Laird, P. N. and P. C. Wason (1977) Thinking: Readings in Cognitive Science, Cambridge University Press. (Part VII Imagery and Internal Representation)

A thought is generally interpreted as something expressed in words, and so it is natural to assume that its underlying representation must be in verbal form. But words and propositions are not the only kinds of thing of which individuals are consciously aware when they are thinking. They also experience imagery; they 'see' pictures in their mind's eye with varying degrees of intensity. Do words and pictures exhaust the possible candidates for thought? The followers of Freud postulate unconscious determinants of thought, and even unconscious fantasy; and Chomsky has postulated very abstract structures in the mind which underlie the use of language and other cognitive operations. Traditionally, however, the main candidates have been words and images.

Mills, Michael I. (1985) "Image Synthesis: Optical Identity or Pictorial Communication? in Proceedings Graphics Interface '85. Canadian Info. Processing Society. May 27-31, 1985.

This paper reviews some ideas from E. H. Gombrich (an art historian) and Julian Hochberg (a perception psychologist) on artists' attempts to simulate reality in painting. These ideas suggest that workers in image synthesis enlarge the scope of their mission. Rather than trying to get computers to make images which are indistinguishable from direct perception, they should pay more attention to the use of computer graphics for "pictorial communication"--where departures from objective realism can sometimes lead to more effective displays and where the mental process of image interpretation should itself be a legitimate focus of research and experimentation.

Norman, Donald A. (ed.) (1981) Perspectives on Cognitive Science, Ablex Publishing Corp., Norwood, New Jersey.

Oatley, Keith G. (1977) "Inference, Navigation and Cognitive Maps." in Thinking: Readings in Cognitive Science, Johnson-Laird and Wason (eds.) Cambridge University Press.

It was probably about 3,500 years ago that the islands of the Pacific Ocean began to be explored and settled (Emory, 1959). By 1,000 years ago, islands far away from the central groups, Hawaii to the north, Easter Island to the east, and New Zealand to the south-west were peopled by Polynesians. To reach these outlying islands required long open sea voyages of 1,000 to 2,000 miles. Navigation of all kinds is a complex cognitive skill, but as practised by the seafarers of Oceania, it is a skill which is entirely mental and perceptual, using no instruments of any kind. It is based on processes of inference within the structure of a cognitive map.

Peterson, Michael Paul (1982) Map, Image and Mind: A Pattern Quality Test of Some Graduated Symbol Maps, State University of New York, Buffalo. Dissertation Abstracts International, July 1982, Vol. 43(1-B), p. 78.

A major achivement of cartography in the past three decades has been an epistemological shift from a state where the design of maps was subject only aesthetic principles to a position where it could be considered from more scientific perspectives. Certain aspects of the behavioral (stimulus/response) form of research, however (especially the concentration in perception of individual symbols), have been criticized. Some cartographers have suggested a closer look at the internal, or mental, aspects of map communication.

Schlegel, Robert E. and William F. Storn (1983) "Speed-Accuracy Tradeoffs in Spatial Orientation Information Processing" in Proceedings of the Human Factors Society - 27th Annual Meeting.

A study was conducted to further evaluate the Manikin Task, a test of spatial orientation information processing. The objectives of the study were to determine the speed vs. accuracy tradeoff characteristics of the task and to assess performance on the task under theinfluence of ethyl alcohol. Response times and accuracy were measured on five subjects over a five-week period. Analysis of the data indicated a definite decline in accuracy corresponding to a forced decrease in response time. The effect of alcohol was evidenced by a change in the slope of the speed-accuracy tradeoff function.

Senders, John W., D. F. Fisher & R. A. Monty (1978) Eye Movements and the Higher Psychological Functions, Lawrence Erlbaum Associates, New Jersey, 1978.

Shepard, R. N. & J. Metzler (1977) "Mental Rotation of 3-D Objects" in Thinking: Readings in Cognitive Science by Johnson-Laird, P. N. & P. C. Wason (eds.), Cambridge University Press.

Human subjects are often able to determine that two two-dimensional pictures portray objects of the same three-dimensional shape even though the objects are depicted in very different orientations. The experiment reported here was designed to measure the time that subjects require to determine such identity of shape as a function of the angular difference in the portrayed orientations of the two three-dimensional objects. This angular difference was produced either by a rigid rotation of one of two identical pictures in its own picture plane or by a much more complex, nonrigid transformation, of one of the pictures, that corresponds to a (rigid) rotation of the three-dimensional object in depth. This reaction time is found 1) to increase linearly with the angular difference in portrayed orientation and 2) to be no longer for a rotation in depth than for a rotation merely in the picture plane....all subjects claimed 1) that to make the required comparison they first had to imagine one object as rotated into the same orientation as the other and that they could carry out this 'mental rotation' at no greater than a certain limiting rate; and 2) that, since they perceived the two-dimensional picutres as objects in three-dimensioanl space, they could imagine the rotaion around whichever axis was required with equal ease.

Wicken, Christopher D. (1984) "Attention & Perception" Engineering Psychology and Human Performance, Merill Publishing Co., Chapt. 7.

The limitations of human attention, like those of working memory, constitute one of the most formidable bottlenecks in human information processing. We can all easily relate instances when we failed to notice or attend to the words of a speaker because we were distracted or our attention was directed elsewhere or occasions on which we had so many tasks to perform that some were neglected. These intuitive examples of failures of attention may be desribed more formally in terms of three categories: 1. The limits of selective attention. 2. The limits of focused attention. 3. The limits of divided attention.

Wicken, Christopher D. (1984) , "Non Verbal Perception" Engineering Psychology and Human Performance, Merrill Publishing Co., Chapt. 5, p. 163 - 183.

This chapter on nonverbal perception will focus on perception of stimuli that do not generally share one or more of these three properties. One concern will be the perception of objects or texture. Here the physical stimulus does not bear an arbitrary symbolic relation to the subject's concept of that stimulus, but bears a direct analog relation to it. The term "analog" implies that some physical equivalence exists between the stimulus and its mental representation. The equivalence may be achieved by continuous transformations of rotation, magnification, distortion, or translation. Thus a pilot's mental representation of an aircraft in space should have a direct analog correspondence with the true orientation of the actual aircraft. As a second contrast, unlike verbal stimuli, the information to be dealt with in in the present chapter is often perceived first as a set of lines and angles joined together, but is perceived intially as a whole box into its constituent elements.

Wimmer, K. E. (1978) "Research on Human Interface Considerations for Interactive Text Generation" Evolutions in Computer Communications, Proceedings of the 4th International Conference, North Holland Pub. Co., Amsterdam.

40 operators, most of them secretaries, were observed operating word-processors (WP), with and without display. The aim was to find out, how a WP interfaces to the operators' cognitive skills and motivations. The operators' actions were protocolled for several weeks, 8 hours per day, under normal working conditions. Adapted tape recorders served as

recording devices. These were plugged into a WP's bus as recording devices. These were plugged into a WP's bus and protocolled every interaction between WP-keyboard and processor. Protocol data were run through evaluation programs, and operation characteristics were derived and compared for different WPs, operator types and tasks. Operators reported, via a set of questionaires, on their working conditions and gave their opinions on the WPs' operational aspects. A summary of results is given.

Woods, David.D.(1984) "Visual Momentum: a concept to improve the cognitive coupling of person and computer" Int. Journal of Man-MachineStudies Vol 21, p.229-224.

Computer display system users must integrate data across successive displays. This problem of across-display processing is analogous to the question of how the visual system combines data across successive glances (fixations). Research from cognitive psychology on the latter question is used in order to formulate guidelines for the display designer. The result is a new principle of person-computer interaction, visual momentum, which captures knowledge about the mechanisms that support the identification of relevant data in human perception so that display system design can support an effective distribution of user attention. The negative consequences of visual momentum on user perfiormance are described, and display design techniques are presented to improve user across-display information extraction.

Color

Bloomfield, John R. (1979) "Visual Search with Embedded Targets: Color and Texture Differences" Human Factors, 21(3), 317-330.

Two embedded target visual search displays were used in three kinds of experiment. One display had a color and the other a monochrome texture background. In each trial of each experiment a single target was presented. First, 28 observers rated the discriminability of five color and four monochrome targets from the color and monochrome backgrounds, respectively. Second, five observers searched the color and six the monochrome display for the appropriate targets and, after practice, there were 60 trials per observer per target. Third, using the five observers who searched the color display and four of the six who searched the monochrome, the extent into the perphery that they could see the appropriate targets when the displays were exposed for 0.3 seconds was measured. Analysis of the data showed that, for the color displays, simple equations, developed for competition search situations, could be used to relate together the three types of measure. The equations were less successful for the monochrome display.

Bloomfield, John R., Jerry Wald & Deborah A. Smith (1979) "Target Discriminability in Complex Search Situations" in Proceedings of the Human Factors Society - 23rd Annual Meeting.

Stimuli from Bloomfield's (1979) embedded-target visual search study were used in a series of experiments. The targets differed in color mixture from the nontargets. Target discriminability was measured in several ways: by limiting exposure time, by optical blurring and by introducing neutral density filters. The discriminability measurements were compared to the previously- obtained data in order to discover the best predictor of search performance.

Byrne, Holly & Ronald Summars (1975) "The Selection of Color for the USSR Agricultural Atlas" Auto Carto II, Proceedings of the International Symposium on Cartography and Computing: Applications p. 267-294.

Color-coding, that is, the assignment of colors to things represented on a map, is a complex process and a very important ingredient in map deisgn. The success of map could very well depend on the proper use of color. Using color requires, among other things, a good judgment and a "feel" for color and there are many differences of opinion, even by those with extensive training and experience.
Many questions confront the cartographer when using colors, such as, "Do I use colors just to make the maps more attractive regardless of whether it can be as effective with fewer colors?" The objective of the map should surely have an influence on the answer to whether color should be employed, but the use of process colors, i.e., the use of combinations of only a few basic colors to produce a wide range of tones, will more readily allow one to answer such a question in the affirmative.

Carter, Ellen C. & Robert C. Carter (1981) "Colour and Conspicuousness" Journal of the Optical Society of America, Vol. 71, No. 6, June 1981.

The principle that things are easier to find if they contrast with their environment is expressed quantitatively. Two indices of conspicuousness, relative fixation rate and search time, are shown to be related to the color difference between the target and background objects. The color difference equations used are CIELAB, CIELUV, and the Judd modification of the index of fading. None of the equations is superior to the others. Furthermore, neither Judd's modification nor Semmelroth's adjustment accounts for effects of surround lightness. It is suggested that color difference be used as a tool for design and evaluation of visual displays, for construction of color codes to optimize search time, and as a generalization of achromatic contrast in psychophysical research.

Carter, Robert C. (1979) "Visual Search and Color Coding" in Proceedings of the Human Factors Society - 23rd Annual Meeting.

Several experiments were conducted to investigate the effects on search time of display and personnel characteristics. Search time increased by an order of magnitude when the number of display items of the target's color increased from one to the display density. Items not of the target's color affected search time to the extent that their color was similar to that of the target. The similarity of the colors was found to be well represented by a color difference calculation. The distribution on the display of target-color items also affected search time. Personnel characteristics, including several measures of ability and experience, were unrelated to search speed.

Christ, R. E. (1975) "Review & Analysis of Color Coding Research for Visual Displays" Human Factors, 17(6), 542-570.

The experimental literature on the effects of color on visual search and identification performance was reviewed. Forty-two studies published between 1952 and 1973 were located that gave results which could be used to determine the effectiveness of color codes relative to various types of achromatic codes. Quantitative analyses of these results indicated that color may be a very effective performance factor under some conditions, but that it can be detrimental under others. Tentative conclusions about the nature of these conditions were derived from the results. A guide for design decisions and an indication of knowledge gaps are also provided.

Christ, R. E. (1976) "Analysis of Color & Its Effectiveness" Naval Air Test Centre, 3rd Advanced Aircrew Display Symposium, Maryland, May 1976.

Highly practiced subjects were used in a series of experiments to investigate the effectiveness of color coding relative to coding with letters, digits, and familiar geometric shapes. These experiments were concerned with unidimensional and bidimensional displays and with relatively simple single tasks (choice reaction, search and locate, and multiple target identification). The results were analyzed and are presented in a manner which will maximize their usefulness as a practical guide for when and where to use color in displays.

Christ, Richard E. & Warren H. Teichner (1973) "Color Research for Visual Displays" U. S. Joint Army-Navy Aircraft Instrumentation Research Program, July1973.

The experimental literature on the effect of color on visual search and identification performance was reviewed. Forty-three studies published between 1952 and 1973 were located that gave results which could be used to determine the effectiveness of color codes relative to various types of achromatic codes. Quantitative analyses of these results indicated that color may be a very effective performance factor under some conditions, but that it can be detrimental under others. Tentative conclusions about the nature of these conditions were derived from the results and these conclusions were supported by an exploratory experiment. A guide for design decisions and an indication of knowledge gaps are also provided.

Cook, J. F., W. D. Moss and C.M.Crawshaw (1982), "An Evaluation of a Radar Display Showing Target Aspect in Colour". Journal of Navigation (GB), Vol.35 Issue 2, 1982.

An experiment is described in which colour-coded information concerning the aspect of target ships was provided in addition to a relative-motion radar display. This was compared to the normal relative-motion display alone. The perfomance of twenty-one experienced seafarers on six exercises was assessed by five expert judges as an index of display effectivenes. The method of evaluation was found useful and practical, while user reports were shown to be inappropriate. No overall difference between the three displays was found; the reasons for this are discussed and the conclusion is drawn that training is requred to gain the benefit of colour in a display.

Cuff, David J. (1975) "Conflicting Goals in Choosing Colors for Quantitative Maps" Auto Carto II, Proceedings of the International Syumposium on Cartography and Computing: Applications p. 267-294.

In choosing colors for a map or series of maps it is essential to first identify the purpose of the color scheme, and second to be aware of the three dimensions of color (hue, darkness, and intensity) and how they can be used to accomplish that purpose. An important distinction to make is between the use of colors for qualitative differences versus using colors to symbolize quantitative differences between map areas. This discussion will focus on colors used for quantitative differentiation conflict. (Minor goals may be identified tentatively as follows: equal-appearing intervals, hues appropriate to the theme being mapped, and variety in colors from one map to the next.)

Engel,F.L.(1982) "Information selection from visual display units". In E.Grandjean and E.Vigliani (Eds) Ergonomic Aspects of Visual Display Units.Taylor and Francis, Ltd,London, 1982.

Colour can be a very useful expedient for improving the surveyability of electronically displayed text. With the introduction of Viewdata and Teletext, the use of colour in text displays has increased considerably. Its appropriate application, however, required a subtler approach than is standard today. To that end the 'conspicuity area' is proposed as a means for assessing more quantitatively the influence of colour on the visual prominence of embedded entities of text. Experimental evidence for the relevance of this concept is given.

Gershon, Ron (1985) "Aspects of Perception & Computation in Color Vision" Computer Vision, Graphics & Image Processing, 32, 244-277.

One of the areas which has received little attention in computer vision research is color vision. The main reason for this was technological: color digitizers and monitors were not very common, and the amount of computation and memory needed for chromatic image processing were large and expensive. This is no longer a major factor. In addition, recent studies suggest that color contributes to other visual processes, and therefore cannot be considered as a mechanism which merely adds beauty to scenes. It should be an integral part of any computer vision system, and justifies a more complex treatement. This paper reviews the main aspects of color vision, which originate from different disciplines of science. Physical concepts regarding light and reflection govern the appearance of objects. The structure of the visual system (mainly in primates) may help the construction of computational models of color vision. Psychophysical experiment are a resource of theories which can be implemented and test as part of a vision system. The discussion in this paper includes the different facts and problems they pose some of which are currently being explored.

Haider, M., M. Kundi and M.Weibenbock 'Worker strain related to VDUs with differently coloured characters'. In Ergonomic Aspects of Visual Display Terminals, by E.Grandjean and E.Vigliani (Eds) Taylor and Francis, Ltd, London.

In an experimental setting the differential strain of work on three different VDU's with green and yellow characters has been studied on 13 trained VDU workers; nine office workers served as controls. The usefulness of certain physiological and psychological indicators to characterize the strain on VDU workers is demonstrated. Concerning work with VDU's with green and yellow characters, we found in some indicators no differences at all, while some showed beneficial effects of yellow, and some of green, characters. Performance showed improvements over the three-hour working period, with a higher rate of improvement for work with yellow characters. The decrease of visual acuity during work correlated well with different lengths of working spells and the occurrence of breaks. Furthermore, less temporary myopisation occurred for work with yellow characters. Significant differences of colour-contingent after-effects (colour adaptations) between VDU workers and controls have been measured by anomaloscope readings for both colours of character. The Muller-Lyer illusion was higher after work. This higher amount of illusion persisted longer for VDU's with yellow characters . Gross changes in subjective state and high rates of asthenopic and other symptoms could be observed with no significant differences beween VDU work with green and yellow characters. Sustained VDU work doesn't change visual receptor functions but leads, according to our results, to functional changes in accomodation mechanism and selective colou adaptation processes. Furthermore, prominent changes in the state of well-being could be demonstrated.

Hansen, Oliver K.(1984) "Human Factors Design Consideration in Military Colour Graphic Design Issues in User Interface Design" In Proceedings of the 5th Annual Conference and Exposition Vol.1 - Tutorials. National Computer Graphics Association,1984.

Military Applications of electronic color graphic displays are growing at an accelerating pace. Hardware advances are now outpacing our formal knowledge of display coding and formatting. This tutorial attempts to identify major problems, considerations and principles relevant to the design of color graphic display presentations for military systems operators. The lecture session covers: 1) A review of the human visual system and color perception, 2) A review of currently available hardware technologies for high resolution colour graphic displays, 3) Some key design issues relating to image generation and formatting and 4)

Identification of preliminary guidelines for color coding and formatting of display events. This printed summary is limited to topics 3 and 4.

Heath, A. M., R. B. Flavell (1985) "Color Coding Scales & Computer Graphics" in Proceedings Graphics Interface '85, Canadian Info. Processing, May 27-31, 1985.

Colour is a powerful tool when used to code information on a graphics display, and the growth in the number of colour displays increases the importance of understanding the potential of colour coding. This paper described the ways in which colour can be used to code information, and reviews previous guidelines. An experiment examining the quantitative, rather tahn qualitative, use of colour in ten different ordinal scales is described. The results generate new guidelines that demonstrate the importance of displaying a reference scale, and show that when applied out of context the previous guidelines can significantly underestimate the power of colour coding. Keywords: human factors, color coding scales, color models.

Hopkin, David V. (1977) "Color Displays in Air Traffic Control" IEEE Conference Publication No. 150, Displays for Man-Machine Systems, p. 46-49.

Colour displays are being considered for air traffic control because they now constitute a practical alternative to monochrome on the grounds of technical development, reliability and cost. They have not been specially developed for any new or existing role in air traffic control, but can be grouped with other display innovations, such as plasma displays, light emitting diode displays, rear port displays, and deformagraphic displays, for which an application in air traffic control is sought. The impetus to study colour displays now, rather than ten years ago or ten years hence, emanates form display technology. No new and urgent human factors needs or pressing air traffic control requirements have suddenly made colour coding imperative. It would indeed be more felicitous if the advent of colour displays happened to coincide with the first indispensable operational need for them in air traffic control.

Joblove, George H., Donald Greenberg "Color Spaces for Computer Graphics" Computer Graphics, Vol 12(3), p. 20-27, Aug. 1978.

Normal human color perception is a product of three independent sensory systems. By mirroring this mechanism, full-color display devices create colors as mixtures of three primaries. Any displayable color can be described by the corresponding values of these primaries. Frequently it is more convenient to define various other color spaces, or coordinate systems, for color representation or manipulation. Several such color spaces are presented which are suitable for applications involving user specification of color, along with the defining equations and illustrations. The use of special color spaces for particular kinds of color computations is discussed.

Judd, D. B. & G. Wyszecki (1975) Color in Business Science & Industry, John Wiley & Son, 3rd Edition.

Kaufman, Lloyd (1975) "The Uses of Color" Auto Carto II, Proceedings of the International Symposium on Cartography & Computing: Applications p. 267-294.

...The map, by virtue of its pictorial properties, allows the observer to process information in parallel and in rapid sequence and relate it quite directly to meaningful categories of knowledge... However...there is little point in transmitting a large amount of information per unit time if the receiver is incapable of handling it. While it may be possible to represent many different dimensions simultaneously in a single map, we can reach a limit beyond which the human map reader will become confused. Thus, the scientific study of the human as an information processor is quite pertinent ot the task of the mapmaker who wants to transmit as much information to the mapreader as can be conveniently handled. To do this he must take into account the amount of time that the reader has available to study the map, the way in which the information is to be represented, e.g., in alpha-numeric form or in terms of coded shapes, the legibility of the elements of the map, the purpose for which the map is intended, and so forth. My main focus in this talk is on color as a means for providing information in maps. Thus, color, as you all know, can be used to replace or supplement alpha-numeric symbols. It is obvious to all of us that such a use of color can have important effects on the rate at which information is communicated to the reader. There must, of course, be a trade-off between the value inhering in the use of color and the economics of color reproduction. I shall...deal... with the idea that a better understanding of how the human being senses and uses color can enhance the effectiveness of the application of color in mapmaking.

Kiebs, M. J., J. D. Wolf, J. H. Sandvig "Color Display Design Guide" Honeywell Inc., Minneapolis MN Systems & Research Centre, Office of Naval Research, Arlington, VA, Oct. 1978.

The objective was to develop a design guide for the use of color in advanced avionics displays. Study results are presented in two parts. Part I presents principles for use of color, plus supporting data where such data exist. Principles of Part I are general and can be applied in virtually any application involving color coding of display information. Part II represents the application of these principles to real-world cockpit displays. Recommended color codes are developed for application to electronic displays in fighter/attack aircraft. Examples of representative display formats incorporating the recommended coding are provided.

Kopala, Carole Jean (1979) "The Use of Color-Coded Symbols in a Highly Dense Situation Display" in Proceedings of the Human Factors Society - 23rd Annual Meeting.

The effectiveness of redundant color-coding for displays used by highly-loaded operators performing a series of complex tasks has never been clearly demonstrated. Pilot flight performance and threat recognition performance using two coding conditions for a threat display were compared in a simulated mission. One coding condition consisted of shape-coded symbols, the other of symbols that wer both color and shape coded. Redundant color-coding was found to significantly reduce both response time and error rate.

Krebs, M.J. and J.D.Wolf (1979)" Design Principles for the Use of Colour in Displays" Proceedings of the Society for Information Display, Vol.12, No.1, p 10-15.

A set of principles is provided to aid the designer in making decisions about when, where, and how to use colour coding in a cariety of applications. The necessity of analyzing the operator's task and how color might aid performance is stressed. Effective use of colour requires logical analysis of the function it will serve. Examples of a variety of color coded aircraft displays are provided to illustrate key points.

Marcus, Alan (1982) "Color: A Tool for Computer Graphics Communication" in The Computer Image, Greenberg, Donald, et al., Addison-Wesley Publishing Co.

The experience of color, although no always conscious, is a potent one. To the person inexperienced with its use, color is influential, mysterious, and seemingly uncontrollable. In the earliest civilizations, every person contributed to the creation and use of color. As society became more differentiated, high priests of color emerged; artists and designers became skilled in the discipline of color. In today's "post-industrial" society or "information age," the situation is similar to earliest times in terms of color. Modern technology has placed within the hands of the average person the ability not only to receive color (printed publications, television, and so on), but to create color and to communicate with it. Nowhere is this truer than in the world of computer graphics. Computer graphics systems allow users to design their own color worlds and to communicate color to others...

McCormick, John, Gerald Murch, Lyle Leavitt, (1984) "An Experimental Color Monitor for Vision Research" SPIE Proceedings, Vol. 457 Advances in Display Technology IV, The International Society for Optical Engineering, p. 26 - 30.

Visual science refers collectively to the research of the vision process from anatomical, neurological, physiological, psychophysical, opthalmological, and psychological points of view. Each of these disciplines in turn is concerned with some aspect of the multifaceted visual funtion. The work extends from studies of humans to a wide variety of other species with the ultimate goal of understanding this most critical link between living things and the environment.

Meyer, Gary W. and Donald P. Greenberg (1980), "Perceptual Colour Spaces for Computer Graphics" Computer Graphics Vol.14.No.3, Siggraph '80 Conference Proceedings , J. Thomas (Ed) Association for Computing Machinery, New York, 1980.

Meyer, Gary W.and Donald P. Greenberg (1980) "Perceptual Color Spaces for Computer Graphics" ACM Computer Graphics, Vol. 14, No. 3, July 1980, p. 254-261.

Perceptually uniform color spaces can be a useful tool for solving computer graphics color selection problems. However, before they can be used effectively some basic principles of tristimulus colorimetry must be understood and the color reproduction device on which they are to be used must be properly adjusted. The Munsell Book of Color and the Optical Society of America (OSA) Uniform Color Scale are two uniform color spaces which provide a useful way of organizing the colors of a digitally controlled color television monitor. The perceptual uniformity of these color spaces can be used to select color scales to encode the variations of parameters such as temperature or stress.

Miller-Jacobs, Harold H. (1984) "Colour Displays and the Colour Deficient Operator" Proceedings SPIE International Society of Optical Engineers.Vol 457 Advances in Display Technology IV (1984), p.14-15.

The increased use of multi-colour displays in C31 Applications has raised the question of colour deficient operators. By screening operators who are invoved in critical colour discriminations and be the proper deign and testing of the developed product, this concern can be eliminated.

Murch, Gerald M. (1984) "Physiological Principles for the Effective Use of Color" IEEE Computer Graphics & Applications, Vol. 4, No. 11.

Without a doubt, color has come to dominate the information display world. In fact, about 85 percent of the display systems currently sold feature color. Ironically, this situation has developed so rapidly that most people still don't know how to use color effectively. Properly used, color can be a powerful tool to improve the usefulness of an information display system. The inappropriate use of color can seriously reduce the performance of such a system, however.

Most often, color is used in a qualitative rather than a quantitative fashion, that is, to show that one item is different from another, rather than to display relationships of degree. A typical example,... involves color-coding each layer of a multilayer circuit board. Color differentiates the layers but says nothing about their relationships. A simple quantitative extension of the multilayer circuit board might involve placing the layers in spectral order, folowing the popular mnemonic ROY G. BIV (red, orange, yellow green, blue, indigo, violet)... It is impossible to develop a complete set of guidelines for the effective use of color in all applications. We can, however, establish some braod principles based on the mechanisms of human color perception.

Murch, Gerald M. (1985) "Color Graphics - Blessing or Ballyhoo?" Computer Graphics Forum, North Holland, 4, p. 127-135.

The human visual system's capacity and capability to process colour can be applied as a design criterion for colour information displays. This paper reviews key elements in the visual domain of colour, encompassing the visual, perceptual, and cognitive modes and develops a series of recommendations effective colour usage based on these elements. Keywords: human factors, colour perception, user interface, perceptual ergonomics, color and productivity, color physiology, color cognition, color aesthetics.

Naiman, Avi (1985) "Colour Spaces and Colour Contrast" in Proceedings Graphics Interface '85, Canadian Info. Processing Society, May 27-31, 1985.

With the introduction of low-cost colour graphics sytems come a host of problems specifically concerned with the colour aspect of the system. This paper discusses two of these problems: the selection and manipulation of colours by (possibly) inexperienced users, and the automatic selection of colours by the system to achieve high contrast effects on the screen. A new colour model based on colour opponency theory is described. This model is useful both in the user interface and in the automatic selection of high contrast colours.

Olson, Judy M. (1975) "The Organisation of Color on Two-Variable Maps" Auto Carto II, Proceedings of the International Symposium on Cartography and Computing: Applications p. 267-294.

There are many types of maps on which color may serve a useful function. Color may be used to enhance or clarify information, it may be used to increase the visual appeal of a map, and in some cases it may be an indispensable ingredient in the sytem of encoding complex information. An example of the use of color to encode complex information is its use on two-variable "cross-maps" such as those currently produced by the U.S. Bureau of the Census. This technique presents two quantitative variables on the same map, and the symbol system, a fairly complex one when considered in detail, is a set of color combinations. The construction of a color scheme for two-variable maps must be based on several logical consideratins, or restraints, such that the scheme forms a coherent system. It is the development of this set of color combinations and its logic relative to the map message that is discussed in this paper. Such a color system represents a specific employment of color and is presented as a sort of "case study".

Radl, G.W. "Experimental investigations for optimal presentation-mode and colours of symbols on the CRT screen." In Ergonomic Aspects of Visual Display Terminals by E. Grandjean and E. Vigliani.

Methods and main results of four different experiments for the adaptation of information presentation of VDUs to the human perception are decribed. The first experiment shows that frames can bring an improvement in readability and visual comfort, when the VDU is positioned unfavourably under potical conditions which can caue glare effects. The second experiment demonstrated that coloured symbols bring an advantage en readability of the information on the screen, when the use of colour is not connected with a decrease of the luminescence level on the disp;ay and colours are dituated within the yellow-green part of the spectrum. The performance of man in identifying colours of simple symbols on different colouted backgrounds on a colour TV screen was investigated in the third experiment. The results are an impressive demonstration of the problems in the application of multicolout CRT displays. In the last experiment it was found that the presentation-mode of dark characters on a light background on the VDU screen provides better readability and higher visual comfort than thepresentation of light characters on a dark background.

Sloan, Kenneth R. Jr., & Christopher M. Brown (1979) "Color Map Techniques" Computer Graphics & Image Processing, 10, 297-317.

Full color, raster-scan displays are increasingly popular media for computer graphics. Several bits of information about every picture element in a raster image can be stored in a local image memory and used to produce a video display. A color map is a look-up table interposed between the image memory and the video display generator which can be used to implement an arbitrary mapping from image-memory values to display values. We present several techniques and applications which depend upon such a color map to provide fast and flexible changes to the display without rewriting the image memory.

Smith, S. L. (1973) Display Colour Coding for Visual Separability, Bedford, Mass: Mitre Corporation, Technical Report MTS -10, August, 1973.

Smith, S. L. (1963) "Color Coding and Visual Separability in Information Displays" Journal of Applied Psychology, Vol. 47, No. 6, p. 358-364.

12 experimental Ss performed both visual search and class counting tasks, viewing displays containing 20, 60, or 100 items. Each item consisted of a vector, letter, and 3-digit number grouped together, and was presented as white-on-black in some displays, or in 1 of 5 colors. The color code was redundant with the 5 class-designator letters that were used.

Average search and counting time, and counting errors, increased with increasing display density (number of items). None of these measures varied significantly among the 5 different target classes (colors). Addition of the redundant color code resulted in an average time reduction of 65% in the visual search task and 69% in the counting task, with a reduction of 76% in counting errors.

Truckenbrod, Joan R. (1981) "Effective Use of Color in Computer Graphics" Computer Graphics. Vol. 15, No.3, August 1981.

Color is a significant component of computer aided visualization of information, concepts and ideas. The use of color in all applications of computer graphics enhances the image, clarifies the information presented, and helps distinguish features that are obscure in black and white pictures. Color is used to differentiate elements in the diagrams so that the comparative information is read and understood rapidly and acurately. Color visualization techniques increase the amount of information that can be integrated into the visual message or picture, and thus create layers of information. It is clear that research and discovery can be supported and enhanced by color application, or inhibited by ineffectual use of color. In order to effectively utilize color in the visualization of ideas, information, or concepts, the role of color in various applications must be examined, and the perceptual behavior of color must be delineated. The basic principles of color theory have been discussed to provide a fundamental understanding of the characteristics of color and the manner in which colors interact with one another. Based on these principles, the user will be better able to utilize color in an effective manner relative to specific applications in color graphics.

Tullis, Thomas S. (1981) "An Evaluation of Alphanumeric, Graphic & Color Information Displays" Human Factors. 23(5), 541-550.

Four different types of CRT display formats were evaluated in the context of a computer-based telephone line testing system. The formats considered were narrative, which used complete words and phrases; structured, which used a tabular format; black-and-white graphics, which used a schematic of the telephone line; and color graphics, which also used a schematic but added color coding. The evaluation measured speed and accuracy of the subjects' interpretation of the displays of test results. Accuracy did not significantly vary with format but speed did. Response times for both graphic formats were consistently shorter than those for the narrative format. With additional practice, however, reponse times for the structured format were just as short. There was no significant difference between response times for the black-and-white graphic and color graphic formats.

Controls

Beringer, Dennis B. (1979) "The Design and Evaluation of Complex Systems: Application to a Man-Machine Interface for Aerial Navigation" in Proceedings of the Human Factors Society - 23rd Annual Meeting.

Sytematic and economic design and evaluation strategies were applied to a computer-generated 4-D aerial navigation system. During the evaluation eac [illegible] 24 experienced instrument pilots received training in a PLATO-based digital flight simulator using either a keyboard entry/static map, keyboard entry/dynamic map, or touch entry/dynamic map system. Tasks performed during the execution of an area navigation course included continuous flight control, navigation data updating, digital data entry, and amended course plotting. Digital data entry training time was comparable for all three systems but the touch-map proved superior for the plotting tasks, greatly reducing training and task execution times while virtually eliminating errors. Subsequent performance evaluation showed that the touch-map reduced flight path tracking error, increased processing rates on a digit-cancelling secondary task, and increased the accuracy of manual plotting operations. It was concluded that a touch entry system could significantly reduce cockpit workload across a wide range of operational environments.

Bernotat, R. K. & K. -P. Gartner (1972) Displays and Controls: The Proceedings for an Advanced Study Institute Held At Berchtesgaden in March, 1971, Swets & Zeitlinger NV - Amsterdam.

Blake, Tyler "Beyond 'User Friendly'": Using Human Factors to Evaluate Interactive Graphic Interfaces" (1984) in Proceedings of the 5th Annual Conference & Exposition, Vol. 1- Tutorials, National Computer Graphics Assoc.

A half-day tutorial focusing on the evaluation off interactive graphic interfaces using analytical methods and measurement techniques derived from human factors engineering and applied psychology. Emphasis will be placed on pragmatic methods of modifying traditioanl techniques to deal with the constraints of the contemporary systems development process.

Application examples will include selecting alternative input devices, comparing decision-aiding systems and evaluating graphic display quality. The special problems of evaluating human behavior and performance will be addressed.

Buxton, W., R. Hill, P. Rowley, (1985) "Issues & Techniques in Touch-Sensitive Tablet Input (Extended Summary) in Proceedings Graphics Interface '85. Canadian Info. Processing Society. May 27-31, 1985.

Touch-sensitive tablets and their use in human-computer interaction are discussed. It is shown that in certain contexts such devices have some very important advantages over more common technologies (such as mice and joysticks). The analysis serves two puposes: 1) it sheds light on touch tablets, and 2) it demonstrates how other devices might be approached. Three specific distinctions between touch tablets and traditional devices are drawn. These concern: the signaling of events, multiple point sensing and the use of templates. These distinctions are reinforced, and possible uses of touch tablets are illustrated, with a simple example system. Potential enhancements to touch tablets and other input devices are discussed, as are some inherent problems. The paper concludes with recommendations for future work. General Terms: Design, Human Factors. Additional Keywords and Phrases: touch sensitive input devices.

Card, S.K., W. K. English & B. J. Bun, (1978) "Evaluation of Mouse, Rate-Controlled Isometric Joystick, Step Keys and Text Keys for Text Selection on a CRT" Ergonomics, Vol. 21, p. 601 -613.

Four devices are evaluated with respect to how rapidly they can be used to select text on a CRT display. The mouse is found to be fastest on all counts and also to have the lowest error rates. It is shown that variations in positioning time with the mouse and joystick are accounted for by Fitt's Law. In the case of the mouse, the measured Fitts's Law slope constant is close to that found in other eye-hand tasks leading to the conclusion that positioning time with this device is almost the minimal achievable. Positioning time for key devices is shown to be proportional to the number of keystrokes which must be typed.

In terms of speed and accuracy the mouse was shown to be clearly superior to the other three devices which followed in the order, joy-stick, text keys, step keys. The authors report the rate of movement for the mouse as nearly maximal with respect to the information processing capabilities of hand and eye. Positioning times for the key devices are proportional to the number of keystrokes.

Goodwin, Nancy C. (1975) "Cursor Positioning on an Electronic Display Using Lightpen, Lightgun, or Keyboard for Three Basic Tasks" Human Factors, The MITRE Corp., Bedford, Mass. 17(3), 289-295.

Three basic tasks were designed to measure how fast a user could position a cursor at various locations on an electronic display. The tasks were arbitrary cursor positioning, sequential cursor positioning, and check-reading for errors. Three cursor positioning devices were tested. Both lightpen and lightgun permitted faster cursor positioning than a poorly designed keyboard. These pointing devices were four to five times faster than the keyboard for the arbitrary positioning task, and about twice as fast for the other tasks.

Hutzel, I. and C. Peters (1985)"The current state-of-the-art in user interfaces". Systems and Software (USA) vol. 14, no.3 p 131-40, March, 1985.

Keyboards are the most commonly used devices for getting data into and out of computers. However, there are some easier-to-use devices that are catching on, including mice, trackballs, touchscreens, graphic tablets, touchpads and even voice-input devices. All of them appeal to a class of users who may be intimidated by keyboards. The author reports on the latest products.

Jackson, H. C. (1983)," Keyboard Interface Device". IBM Technical Disclosure Bulletin. Vol.25, No. 11B, April 1983.

Human factors testing on various products, such as the keyboards on typewriters, etc., requires a computer attachment to the typewriter such that the computer can monitor all keyboard activities. Also, the computer must be able to emulate the typewriter keyboard. This article describes a general-purpose interface box which attaches a typewriter, printer or the like or other devices to a computing system.

Janes, C.C. (1983) "Will Touch-Sensitive CRT Screens Replace Control Consoldes?" Mining & Metallurgy Industries Symposium & Exhibit, Assoc. of Universities for Research, Inc., Tuscon, Ariz.

Kitt Peak National Observatory (KPNO) is experimenting with the use of touch-sensitive CRT screens to augment or even replace hardwire control consoles and terminal keyboard control. The author describes an application in which a touch sensitive terminal is used for a large telescope control, discusses the design considerations, and reviews the strengths and weaknesses of the technology.

Karat, J., J.E.McDonald and M.Anderson (1985),"A comparison of selection techniques: touch panel, mouse and keyboard" In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

A study was conducted testing user performance and attitudes for three types of selection devices. The subjects were tested on target selection practice tasks, and in typical computer applications using menu selection and keyboard typing. The study showed an advantage for on-screen touch panel over keyboard selection and for keyboard selection over mouse entry. Differences between this result and those reporting an advantage of mouse selection are discussed.

Klemmer, Edmund T. (1971) "Keyboard Entry" Applied Ergonomics, Bell Telephone Laboratories Incorp., Holmdel, New Jersey, Vol 2, No. 1, March 1971.

Many recent studies of keyboard entry are summarized with particular emphasis on performance data and fundamental questions about the design of keyboards. The role of auditory and visual feedback and physiological measurements are reviewed. Typical speed and error rates are given for several types of situations and operators. Other methods of data entry are considered, as are source documents, ordering of keys, keyboard interlocks, and chord keyboards. These data should be of interest to anyone concerned with the design and use of keyboards or other data entry devices.

Knowlton, K. C. (1975) "Virtual Pushbuttons as a Means of Person-Machine Interaction" Proceedings IEEE Conference on Computer Graphics, Pattern Recognition and Data Structure, May 1975, p. 350-351.

Lam, S.-T. and J.S.Greenstein (1985) "The effects of input medium and task allocation strategy on performance of a human-computer system"In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

The allocation of tasks between human and computer, and the merits of a dynamic approach to its allocation are discussed. Dynamic task allocation requires efficient human-computer communication. This communication may be accomplished in an implicit or explicit manner. A conceptual framework for the study of explicit human-computer communication is introduced and a study exemplifying the use of the framework is presented. This study investigated the effects of two input media and four task allocation strategies on the performance of a human-computer system. The task environment represented a simplified version of an air traffic control scenario wherein computer aid could be evoked by the human to accomplish task sharing between the human and the computer.

Lee, S. K., W. Buxton, K. C. Smith "A Multi-Touch Three Dimensional Touch-Sensitive Tablet" in Proceedings Graphics Interface '85, Canadian Info. Processing, May 27 - 31, 1985.

The transducer that we have developed is a touch-sensitive tablet; that is, a flat surface that can sense where it is being touched by the operator's finger. This in itself is not new. Several such devices are commercially available from a number of manufacturers. What is unique about our tablet is that it combines two additional features. First, it can sense the degree of contact in a continuous manner. Second, it can sense the amount and location of a number of simultaneous point of contact. These two features, when combined with touch sensing, are very important in respect to the types of interaction that we can support. Some of these are discussed below, but see Buxton, Hill, and Rowley (1985) and Brown, Buxton and Murtagh (1985) for more detail. The tablet which we present is a continuation of work done in our lab by Sasaki et al (1981) and Metha

(1982).
In the presentation which follows, we focus mainly on issues relating to the transducer's implementation. Two important contributions discussed are our method of scanning the tablet surface, and our method of maintaining high resolution despite the surface being partitioned into a discrete grid. Additional technical details can be found in Lee (1984).

Ritchie, G. J. and J.A. Turner (1975) "Input Devices for Interactive Graphics." International Journal of Man-Machine Studies, 7, p. 639 - 660.

Interactive graphic systems provide the potential for natural and efficient man-machine communicaiton. In order to exploit fully this potential and provide a conceptually simple man-computer interface, the graphic input and output devices must be closely integrated. This paper classifies and surveys the basic peripheral hardware, in particular that relevant to graphic data entry, and relates the merits of each device to the interaction process.

Rouse, William B. "Design of Man-Computer Interfaces for On-Line Interactive Systems" Proceedings of the IEEE, Vol. 63, No. 6, June 1975, p. 847 -857.

An attempt is made to integrate a wide range of material into a conceptual structure for the design of man-computer interfaces for on-line interactive systems. Typical roles for the human in man-computer systems are considered. Suggestions for the design of systems are developed in discussions of displays and input devices, visual information processing, and mathematical models of human behavior. Possible developments and avenues of research in man-computer systems are suggested.

Usher, D. M. (1983) "Comparison of a Touch-Sensitive VDU & Computer-Aided Keypad for Plan Control" Displays Technology & Applications, Butterworth & Co. Ltd., July 1983.

The technology of touch screens is discussed with emphasis on the developmnet of appropriate software and human factors. A touch screen was compared with an intelligent keypad in an experiment in which CEGB personnel controlled simulated plant. Users preferred the touch screen in normal conditions and particularly for emergency working. Also, a statistically significant improvement in plant controllability was recorded when the touch screen was used in place of the keypad. Touch screens are seen to possess many advantages over conventional man-machine interfaces. Their use is shown to be appropriate in applicaitons such as alarm analysis, data and mimic selection and interactive graphics as well as for controlling plant.

Van den Bos, Jan (1978) "Definition and Use of Higher-Level Graphics Input Tools" Computer Graphics, 12(3), p. 38 - 42.

A proposal is made for the definition of 'tools', high-level graphics input functions based on the six primitive input classes Clock, Pick, Button, Key, Valuator and Locator. Tools are defined in terms of input expressions, the operands of which are themselves tools, the definition of which may be nested inside this tool. Input expressions are written much like production rules in phrase structure grammars. Determining whether a tool is 'satisfied' can therefore be done most advantageously by an input expression parser. Tool definitions may occur in-line or stored in a library. Thet are activated by a 'create' primitive, which creates an instance of the tool and causes the input expression to be made active. The parser then determines whether a tool is actually used. Following a 'read' issued to the tool, the tool body generates the returned information as specified by the tool definition. Tools may be explicitly freed by a 'free' primitive; in the case of nesting tools are freed implicitly when the surrounding tool is freed.

Using this approach to higher-level input primitives, a programmer does not have to think about graphics input in terms of awaiting events, interrupts and the like. The creation of a defined tool implies a function awaiting action from the tool. Keywords: computer graphics, graphics input, high-level input tools, interaction, input devices, graphics tools.

Design

Andriole, Stephen J. (1982) "The Design of Microcomputer-Based Personal Decision-Aiding Systems", IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC - 12, No. 4, July/Aug. 1982.

Over the past ten years we have witnessed a transformation in the computer-based problem-solving process. In the early 1970's computer-based information, decision, forecasting, and evaluation software systems were clumsy, barely interactive, and generally resident on relatively inaccesible macrocomputer mainframes. By the mid-1970's significant progress had been made via the use of minicomputers and microcomputers and the introduction of problem-solving algorithms which for the first time began to recognize "users" as an integral part of the problem-solving process. ...In the late-1970's computer-based decision-aiding systems of all kinds continued to proliferate. But their development by and large was driven by enhancements made in hardware areas; problem-solving software was not significantly altered from a user-computer perspective. The next generation of computer-based problem-solving is by no means dependent only upon advances in computer hardware. Second, we must jettison those conventional programming practices which underplay the role of situational, physiological, cognitive, and problem-specific knowledge-based variables in the computer-based problem-solving process; and third, we must reject assumptions which directly or indirectly cast the hardware/software system in only a passive or supporting role. Instead, we should design systems which are adaptive to their users, problem-solving situations, and to past problem-solving experiences.

Bailey, Robert W. (1983) Human Error in Computer Systems, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Foley, James D. (1984) "Managing the Design of User-Computer Interfaces" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Sessions, National Computer Graphics Assoc.

Presented here is a management approach embodying a design methodology we have been using for some time. We discuss several critical steps or stages of design which are frequently ignored, and give examples of the activities performed at each stage of the design. We describe the key role played by the "user interface architect", who is to the user interface implementation team as an architect is to the building contractor. Finally, we discuss several ways of integrating human factors expertise, into the design process. We discuss in passing human factors and psychological issues, design guidelines, definition languages, prototyping tools, experimental results, user performance models, and documentation paradigms to show their proper use in the design process, but we do not attempt to be exhaustive or definitive.

Foley, James D. (1984) "Human Factors in Computer Systems: A Management Perspective" in Proceedings of the 5th Annual Conference & Exposition, vol. 1 - Tutorials, National Computer Graphics Assoc.

The quality of a system's user-computer interface is increasingly becoming a major determinant of success in the marketplace. Attributes such as ease of use, speed of use, user-friendliness, consistency, context-sensitive help, etc., are demanded rather than requested. Published software reviews emphasize not only functionality but also user interface and user documentation quality.

The purpose of this tutorial is to help managers develop strategies for designing user interfaces.

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Foley, James D., Victor L. Wallace (1974) "The Art of Natural Graphic Man-Machine Conversation" Proceedings of the IEEE, Vol. 62, No. 4, Apr. 1974.

The design of interactive graphic systems whose aim is good symbiosis between man and machine involves numerous factors. Many of those factors can be judged from the perspective of natural spoken conversation between two people.

Guiding rules and principles for design of such systems are presented as a framework for a survey of design techniquees for man-machine conversation. Attention is especially focused on ideas fo action syntax structuring, logical equivalences among action devices, and avoidance of psychological blocks to communication.

Foley, James F., Victor L. Wallace, Peggy Chan (1984) "The human Factors of Computer Graphics Interaction Techiniques" IEEE Computer Graphics and Applications Vol. 4, No. 11, 1984.

The promise of interactive graphics is to provide a user-computer communications medium that is at once benign, responsive, and graphic. We expect it to be benign and responsive in the same sense a trusted servant is expected to be. We expect it to be graphic with the clarity and richness of communication that only graphic communication presents. When a person uses an interactive graphics system to do real work, he wants the system to virtually disappear from his consciousness so that only his work and its ramifications have a claim on his energy.

This promise is frequently not fulfilled. Designers of graphics systems--software and hardware-- often lack the intuition, knowledge, and experience necessary to "engineer" the forms of dialogue between user and computer to best advantage. The fault lies partly in a lack of current literature, partly in a lack of educaitonal opportunities, and partly in our lack of knowledge of methods and information structures by which such designers can be sucessful.. Well-designed systems are usually the result of a diligent, essentially creative, enterprise.

We believe that one of the most important elements in the design of interactive user-computer interface is the selection of the devices and techniques by which the user performs elementary tasks. The purpose of our work is to provide a systematic structure to aid the designer in making this selection.

Gardner, Arthur, Tom Mayfield and Martin Maguire (1985) " Human factors guidelines for the design of computer-based systems". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

The HUSAT Research Centre has been awarded a four year contract by the U.K. Ministry of Defence (Procurement Executive) to produce a new handbook of human factors design guidelines and associated training for use by the Royal Navy and Industry. The paper describes the project's aims and plans reports progress and seeks to stimulate discussion by presenting an outline of the handbook's proposed structure.

Guedj, Richard A., Paul J. W. ten Hagen, F. Robert A. Hopgood, Hugh A. Tucker, David A. Duce, (1980) Methodology of Interaction, North-Holland Publishing Co., Amsterdam, New York.

Hitt, W.O., H. G. Schutz, C.A. Christner, H. W. Ray & L.J. Coffey (1971) "Development of Design Criteria for Intelligence Display Formats" in Engineering Psychology: Current Perspectives in Research, Appleton-Century Crofts, 1971.

In the design of visual displays to be used in an intelligence center, the design engineer needs answers to a number of questions concerning human factors problems. For instance, what types of formats should be used for the various displays? What types of coding methods should be employed? Is the use of color necessary? What is the best method for displaying trends, or historical data? The purpose of this research program was to attempt to provide answers to questions such as these. Tthe present paper provides introductory and summary information describing the research program . The five following papers describe details of the various experiments.

The function of the intelligence system under study is to collect, process, display, and report pertinent military information about the enemy (or potential enemy). The aspect of this system with which the Battelle research program was primarily concerned is utilization of displays by "centre control" personnel who exercise management over the data-processing activities. Broadly considered, center control exercises a filtering function with respect to directing the processing of system inputs and evaluating the quality of system outputs. An important requirement for visual displays is anticipated in connection with this function.

Hood, N. A., M. A. Shorrock, (1977) "The Design and Development of an Integrated Avionic Display System for Military Aircraft" IEEE Conference Publication, No. 150, Displays for Man-Machine Systems, p. 57 - 61.

This paper describes the techniques used in the design and development of display systems for modern military aircraft, and examines a number of the major problem areas and the methods used to overcome them.

Huchinson, T. Fale, (1981) NewHorizons for Human Factors in Design
Mcgraw-Hill Book Company, 1981 (from Greg McAvoy), p. 20 -111.

The systems approach is a functional approach. Each system, subsystem, and equipment item that is incorporated in the system design must be tailored to specific needs. One should not merely pattern a new system after an existing system if the requirements are different. Those subsystems and equipments that are necessary for the particular mission of the new system will be added; those in a previous model that are not essential must be deleted. Overall, the system must provide as much capability as required by the sponsoring organization, but no more than this capability. Drawing an analogy, if a compact car is ordered, do not design a full-sized limousine!

Although human factors is one of the important systems goals in developing a system, it is not the only goal. Often times the ideal human factors system must be compromised against constraints of cost, delivery schedule, and so forth.

The systems approach involves a new way of looking at all the subsystems of a system. I is inappropriate to think only in terms of "fitting the person to the machine" (through training or selection) or "fitting the machine to the person" (through ideal human engineering). Rather, the best combination of both approaches is called for to meet systems goals within the practical constraints.

Johannsen, G., J.E. Rijnsdorp, and A.P. Sage (1983) "Human System Interface Concerns in Support System Design". Automatica Vol.19, No.6, Nov 1983, p 595-603. *TJ 212 A84*

Man-machine systems exhibit some sort of functional synthesis between humans and machines. Such systems range from elementary interaction to the capabilitieis of machines, the human interface issues become more important. Models of the components of human behaviour as they relate to machine interfaces can contribute to knowledge in the area. That, combined with the history of interface design, indicates some of the areas which need more research.

Joy, Kenneth I. (1985) "A Model for Graphics Interface Tool Development" in Proceedings Graphics Interface '85, Canadian Info. Processing Society, May 27-31, 1985.

A Problem Solving Environment (PSE) is an integrated system that supports the solution of a given problem or a set of related problems. Paramount in the development of such environments is the design, specification and integration of user interface tools that communicate between the system and the user. Typically these interactions are object oriented and involve the interaction with tool parameters, which in many applications (CAD/CAM, Imaging Systems, Image Processing), are represented by graphical data. This paper describes a user-interface tool development system in which both textual and graphical display, and interaction techniques are integrated under a single model. This allows the user to interact with tool parameters in either graphical or textual modes, and to have the parameters displayed in the manner most relevant ot the problem set. Examples are given of the systems use in two different problem sets. Keywords: user interfaces, interaction techniques, problem solving environments.

Kloster, Gregory.V. and Kristine Tischer (1985) "Man-machine interface design process". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

Many systems are built by selecting computers and displays, developing software and only then retrofitting the human, his procedures, idiosyncracies and experiences into the design. Such retrofits are done almost as an afterthought resulting in systems in which the Man-Machine Interface (MMI) is re-engineered within the constraints of a fixed hardware system. To mitigate the risks associated with these approaches, a structured process is being used which focuses on an interdisciplinary and user-involved approach to better engineer the MMI. This approach presumes that man is a starting point in the design process.

Mehlmann, Marilyn (1981) When People Use Computers: An Approach to Developing an Interface, Prentice-Hall, Inc., Englewood Cliffs, NJ.

Rouse, William B. (1981) "Human-Computer Interaction in the Control of Dynamic Systems" Computing Surveys, Vol 13, No. 1, March 1981.

Modes of human-computer interaction in the control of dynamic systems are discussed, and the problem of allocating tasks between human and computer considered. Models of human performance in a variety of tasks associated with the control of dynamic systems are reviewed. These models are evaluated in the context of a design example involving human-computer interaction in aircraft operations. Other examples include power plants, chemical plants, and ships. Keywords and Phrases: human-computer interaction, control, dynamic systems, mathematical models, systems design, task analysis, aircraft.

Shneiderman, Ben (1980) Software Psychology, Winthrop Publishers, Inc.,1980.

Sibert, John L. (1984) "How to Design User Computer Interfaces" in Proceedings of the 5th Annual Conference & Exposition, Vol. 1 - Tutorials, National Computer Graphics Assoc.

Discussion of the Top Down Methodology for User Interface Design

The methodology we will present for designing user interfaces depends on viewing communications between a user and the computer as a conversation. This conversation would include inputs to the computer (outputs from the user), outputs from the computer (inputs to the user), and the sequencing in both time and space of those outputs and inputs. The conversation is viewed exclusively from the user's side of the conversation. That is, in our design process we are not concerned with how the conversation will be implemented. Since we are viewing the user-computer interaction as a conversation it is only natural to adopt a language model of the dialogue. We are actually modelling two languages, the one with which the user communicates with the computer and the language where communication flows from the computer to the user. Both languages can be said to exist on three levels; the semantic, syntactic and lexical. Natural languages can also be considered int hese terms.

Sidorsky, Raymond C. & Robert N. Parrish (1982) "Guidelines & Criteria for Human-Computer Interface Design of Battlefield Automated Systems" in Larson, James A., Tutorial: End User Facilities in the 1980's, IEEE Computer Society Press.

The concept of Behavioral Interoperability is propounded and discussed. Interoperability is recognized as an important design goal with respect to various physical/mechanical components of computerized systems. It would be productive to extend the concept to the behavioral domain. A methodology that has proved useful in deriving guidelines for higher order aspects of human-computer interaction is described. The method is based on a comparative analysis of common or universal transactions associated with existing data processing system. An example of the format and content of a preliminary set of guidelines is provided.

Simcox, William A. (1984) "A Framework for Designing Graphic Representations" in Proceedings of the 5th Annual Conference & Exposition, Vol II - Technical Sessions, National Computer Graphics Assoc.

Computer graphics systems do not automatically create good graphic representations. They merely provide the tools for doing so quickly and easily. The design of effective graphic representations must be based on a systematic procedure that combines knowledge of the data with knowledge of the people who will mentally process the data. In order to develop a systematic procedure, we initially need a way of looking at the display design problem: a design framework. This paper presents such a framework. The framework characterizes all graphic representation in terms of content, format, and organization. These aspects are analyzed to yield a set of design parameters.

Sime, M. E. & M. J. Coombs (1983) Designing for Human -Computer Communication, Academic Press.

St. Clair, Daniel C. & George W. Zobrist (1984) "Designing Computer Graphics Applications: The Man/Machine Interface." IEEE Region Conference, (1984, Wichita, Kansas) Electrical Engineering -- A Century of Serving Society, p. 85-90.

Several important computer engineering components are necessary in the design of computer applications software where computer graphics is used to enhance man/machine communications. The design elements to be described include input, output and processing. Emphasis is placed on using these elements to strengthen the interface between user and ocmputer. Two engineering applications are described.

Thomas, James J. (1984) "User Interface Management System: Origin and Benefits" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Sessions, National Computer Graphics Assoc.

User Interface Management System (UIMS) is a term coined to represent a technological area usually represented in the software between the application and the user. The area encompasses the user to UIMS interface, the UIMS to application interface and the software techniques to construct the UIMS. Researchers from many disciplines, including human factors, graphic illustrations, programming languages, computer graphics and interaction techniques, are focussing their efforts in this and related areas. The motivation is the recognized need for tools to improve the user interface. This short panel introduction represents a brief history, a definition, relationship to early forms packages, and the unique aspects of UIMS.

Wilson, John L., Stuart S. Chen, Steven L. Sadofsky (1985) "Designing a Graphics Application Interface" in Proceedings Graphics Interface '85, Canadian Info. Processing Society, May 27-31, 1985.

This paper describes a systematic approach that can be followed by developers of educational courseware which contains graduated learning capabilities to accommodate a diverse group of users. The paper first presents and discusses a unified conceptual model of a computer-integrated engineering system where graphics plays an important function in the user interface. Second, this paper addresses an overall approach to be taken to interface design and the role graphics can assume. The development of an interface is then examined from both the viewpoint of the user and the courseware implementor. Computer generated displays are included which illustrate the use of the Graphical Kernal System (GKS) in picture generation and modification. The examples are chosen from interactive structural engineering courseware developed by the authors at Lehigh University. Keywords: computer-integrated systems, man-machine communication, interface design, courseware, structural engineering.

Displays

Allen, R. Wade (1984) "Computational Considerations in Real-Time Simulation Computer Graphics" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Sessions, National Computer Graphics Assoc.

The display interface is a critical element in the manual control of vehicles. A well designed display device should, at a minimum, not complicate the human operator's control task; in fact, good synthetic displays should augment the operator's control capability. Advances in digital technology and CRTs are causing a revolution in real time simulation; and general improvements in computer graphics offer a range of computational techniques for creating complex formats.
The problems encountered in digitally generated simulation displays involve computational and refresh update rates, and various effects arising from the quantized nature of digital computations. The human operator requires a display presentation of smooth apparent motion, without significant delay of visual information feedback. This paper will discuss the nature and implications of these various artifacts.

Badre, A. & Shneiderman, Ben (eds.) (1982) Directions in Human/Computer Interaction, Ablex Publishing Corporation.

Barre, Steven H.(1984) "Requirements for future work stations" Proceedings SPIE International Society of Optical Engineers,Vol 457 Advances in Display Technology IV (1984),p.100-105.

..............CRT engineers and work station designers who work with CRT's face significant new challenges based on the changing uses and users of advanced systems. Today, I will focus on some of the changes taking place in display use and discuss some engineering criteria that can be applied to satisfying new needs.

Beringer, Dennis B. (1979) "The Design and Evaluation of Complex Systems: Application to a Man-Machine Interface for Aerial Navigation" in *Proceedings of the Human Factors Society- 23rd Annual Meeting.*

Sytematic and economic design and evaluation strategies were applied to a computer-generated 4-D aerial navigation system. During the evaluation each of 24 experienced instrument pilots received training in a PLATO-based digital flight simulator using either a keyboard entry/static map, keyboard entry/dynamic map, or touch entry/dynamic map system. Tasks performed during the execution of an area navigation course included continuous flight control, navigation data updating, digital data entry, and amended course plotting. Digital data entry training time was comparable for all three systems but the touch-map proved superior for the plotting tasks, greatly reducing training and task execution times while virtually eliminating errors. Subsequent performance evaluation showed that the touch-map reduced flight path tracking error, increased processing rates on a digit-cancelling secondary task, and increased the accuracy of manual plotting operations. It was concluded that a touch entry system could significantly reduce cockpit workload across a wide range of operational environments.

Bernotat, R. K. & K. -P. Gartner (1972) Displays and Controls: *The Proceedings for an Advanced Study Institute Held At Berchtesgaden in March, 1971*, Swets & Zeitlinger NV - Amsterdam.

Biberman, Lucien M. (ed.) (1973) *Perception of Displayed Information*, Plenum Press,1973.

Blake, Tyler "Beyond 'User Friendly': Using Human Factors to Evaluate Interactive Graphic Interfaces" (1984) in Proceedings of the 5th Annual Conference & Exposition. Vol. 1- Tutorials, National Computer Graphics Assoc.

A half-day tutorial focusing on the evaluation of interactive graphic interfaces using analytical methods and measurement techniques derived from human factors engineering and applied psychology. Emphasis will be placed on pragmatic methods of modifying traditioanl techniques to deal with the constraints of the contemporary systems development process.

Application examples will include selecting alternative input devices, comparing decision-aiding systems and evaluating graphic display quality. The special problems of evaluating human behavior and performance will be addressed.

Bloomfield, John R. (1979) "Visual Search with Embedded Targets: Color and Texture Differences" Human Factors, 21(3), 317-330.

Two embedded target visual search displays were used in three kinds of experiment. One display had a color and the other a monochrome texture background. In each trial of each experiment a single target was presented. First, 28 observers rated the discriminability of five color and four monochrome targets from the color and monochrome backgrounds, respectively. Second, five observers searched the color and six the monochrome display for the appropriate targets and, after practice, there were 60 trials per observer per target. Third, using the five observers who searched the color display and four of the six who searched the monochrome, the extent into the perphery that they could see the appropriate targets when the displays were exposed for 0.3 seconds was measured. Analysis of the data showed that, for the color displays, simple equations, developed for competition search situations, could be used to relate together the three types of measure. The equations were less successful for the monochrome display.

Bloomfield, John R., Jerry Wald & Deborah A. Smith (1979) "Target Discriminability in Complex Search Situations" in Proceedings of the Human Factors Society - 23rd Annual Meeting.

Stimuli from Bloomfield's (1979) embedded-target visual search study were used in a series of experiments. The targets differed in color mixture from the nontargets. Target discriminability was measured in several ways: by limiting exposure time, by optical blurring and by introducing neutral density filters. The discriminability measurements were compared to the previously- obtained data in order to discover the best predictor of search performance.

Card, S.K., M.Pavel and J.E.Farell (1985) " Window-based computer dialogues" In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

In recent years a number of systems have used windows as the basis for advanced user interfaces. Yet how exactly users benefit from windows or what features of windows are important for design is neither understood nor has it been studied. Current window designs are given a simple classification. Seven functional uses that have been identified for windows are described. The Window Working Set concept based on operating system theory is introduced for an analysis of space constraints on window use.

Cohen, Andrew D. (1984) "Display Enhancements & Declutter Techniques in Tactical Graphic Displays" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Sessions, National Computer Graphics Assoc.

Several display enhancements were identified and applied to tactical graphic symbols for presentation on a VDT CRT. Each enhancement was evaluated individually with regard to effectiveness and legibility. The problem of display clutter is analyzed along with several approaches for ovecoming display clutter. These approaches and various display enhancements are then combined into a number of simulatd tactical displays. The findings of these studies and recommendations for tactical display format design are then discussed.

Davies, D. W., D. M. Yates (1978) "Human Factors in Display Terminal Procedures" Evolutions in Computer Communications -- Proceedings of the 4th International Conference, North Holland Pub. Co., Amsterdam.

The potential usefulness of computer networks is harmed by the many different styles and conventions of man-computer dialogue. The computer expert enjoys making the transition from one to another but others are less skilful. The conversations are often awkward, frustrating, annoying or even impossible. The paper discusses three kinds of interaction 1) question and answer 2) menu selection and 3) form filling. It comments on the uses for each kind of interaction. Some hybrid types such as a menu included in a text have been found to be useful, others are too complex when the user makes a mistake.

The style of interaction matters. It should be based on a familiar situation, such as human dialogue and be consistent with this. The words used are important and so are the roles adopted by the computer and given to the user. Words such as "my', 'your' are as important as in natural conversation for they confirm the correspondent's roles. Polite words such as 'please' and acknowledgements such as 'good' are useful to create the right atmosphere. These details have been found to be important in computer conversation with untrained users and there is nothing to show that they detract in conversation with experts.

The influence of intelligence in the terminal is mainly beneficial, because it offers the chance of matching to various interactive services. It is not beneficial if it is used by manufacturers to present human interfaces different from any other. It can greatly help the efficiency of all three kinds of interaction.

Fry, Marvin (1982) "Real-Time Graphics in Command/Control Situation Displays" Computer v. 15(4), p. 9 - 17.

Real- time graphics applications are becoming more significant as overall interest in graphics increases and the performance of available hardware improves. The definition of a "real-time" system is somewhat open to debate since the inevitable introduction of processing delay results in few, if any actual real-time systems. In this case, we are using the term to mean systems that are designed to portray a real environment as surveyed by sensors such as radars, direction-finders, or visual observers. These systems seek to indicate positions, speeds, identities, and intents of moving air, ground, and naval objects.

Galitz, Wilbert (1983) "Human Engineering in Screen Design" Journal of Systems Management, Vol. 34, No. 5, Issue #265, May 1983, p. 6-11.

The ultimate design objective for today's information system is 'ease-of-use.' For visual display terminal-based systems the design of screens, and how a person interacts with a computer through them, is a major ease-of-use determinant. Unfortunately much screen design occurs with little to guide it. The human factors involved are not well understood or neglected entirely. It often tends to be unsystematic, inconsistent, and fails to adequately reflect human perceptual and processing capabilites. As a result, many screens in today's system are difficult to use and lack visual clarity.

Granda, Richard E. (1980) "Man/Machine Design Guidelines for the Use of Screen Display Terminals" IEEE Proceedings of the International Conference on Cybernetics and Society, Boston, Mass., p. 583-4.

The visual display terminal has undoubtedly become the primary communication tool between user and computer. It is fair to say that the user has been literally bombarded with a broad range of display terminals varying in hardware and electronic capabilities, character presentation techniques, screen display capabilities, etc. Aided by a variety of input devices (in addition to a standard QWERTY keyboard) such as the lightpen, joystick, and thumbwheels, the user has been given the capability to retrieve and visually inspect varying amounts of data ranging from relatively simple alphanumeric to complex graphical representations.

...The major engineering concentration has been on defining an acceptable set of hardware characteristics which would not deter or inhibit human usage of the terminal itself. As a result of the technological emphasis on hardware, a variety of tools (for the most part anthropometrically and physiologically tested) are availabble to be selected and used as seen proper by a vast host of system software designers, developers, and programmers.

Greenberg,D, et al (Ed) (1982) The Computer Image. Addison-Wesley,1982.

Harpster, J.L. and A. Freivalds (1985) "VDT screen resolution and operator performance". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

The study compared operator performance on a visual search task with the resolution of the display used. The four displays consisted of low, high, high resolution simulating low resolution and hard-copy print as a control. Performance was significantly worst on the low resolution, better for the high resolution modes displays and was best for hard copy print. An explanation based on the spatial frequency characteristics of the display simulating the accomodative system is given.

Heines, Jesse M. (1984) Screen Design Strategies for Computer-Assisted Instruction, Digital Equipment Corp.

Holmes, Richard E.(1984) "Display technology requirements for future workstations",Proceedings SPIE International Society of Optical Engineers,Vol 457 Advances in Display Technology IV (1984),p.88-91.

This paper is complementary to paper 457-24, presented by Mr Steve Barre at this symposium. Barre's paper stated requirements for future workstations that are based on the desire for a specific level of performance from the human operator. He took into account such factors as the minimum data load that should be presented to the operator at one time to achieve adequate work throughput and the minimum level of performance required of the display device in order that the operator can absorb the data with a minimal level of stress and fatigue. Hardware restraints, though not ignored, were second to human factor restraints in Mr. Barre's paper. In contrast, this paper concentrates on what is achievable in the near future from a display hardware standpoint.

Howell, W. C. & Conrad L. Kraft (1971) "Size, Blur and Contrast as Variables Affecting the Legibility of Alpha-Numeric Symbols on Radar-Type Displays" in Engineering Psychology: Current Perspectives in Research, Howell, W. C. & I. L. Goldstein, Appleton-Century Crofts.

Several investigators (1, 12) have discussed the advantages to be gained in radar air traffic control by displaying certain information in symbols electronically printed on a cathode ray tube (CRT). Only recently, however, with the development of such devices as the Charactron and the Digitron, has it become feasible to use letter and number coding for this purpose.

Kime, F. W. (1977) "Evolution of the Man-Machine Interface in Surveillance Radar System" Radar-77: International Conference, London:

Institution of Electrical Engineers, 25-28, Oct. 1977.

Extraction of intelligence from surveillance radar systems for air defence and air traffic control has always relied to some extent upon human interpretation of cathode-ray tube or similar displays. With technological advance, various methods of improving the efficiency of the interface have evolved. This paper briefly traces the history, reviews current techniques and contemplates future possibilities.

Knapp, Beverly G., Franklin L. Moses, & Leon H. Gellman (1982) "Information Highlighting on Complex Displays" in Badre, A. & Ben Shneiderman (eds.) Directions in Human/Computer Interaction, Ablex Publishing Corp.

Recent work in the area of highlighting complex information on computer-driven displays is presented. Emphasis is on two categories of formatting techniques to enhance information asssimilation: coding -- represent information to maximize symbol differentiation, and sequencing -- show information in segments or groups over time. Using a battlefield situation map as a prototype complex display, examples of coding and sequencing information are discussed. Coding examples include double cue coding and color coding; sequencing is represented by windowing, zooming, and selective call-up of aggregated information. The paper provides a list of preliminary guidelines for highlighting information on complex displays.

Lees, Roger (1977) "The Man/Display Relationship" IEEE Conference Publication No. 150, Displays for Man-Machine Systems p. 73-74.

Displays are usually provided to give information or to help someone with their job. Their job is not just to look at the display, but to use the information in doing something else. Often design engineers, concentrating on the technical system, forget that displays form only a part of the operators interest. This has led to several failures and it is the purpose of this paper to look at some of these as well as some successes and to mention a number of considerations beyond the technical ones: considerations for the man/display relationship in a users role. Although we are mainly concerned with cathode ray tube displays, most of the comments apply to mechanical, mimic, instrument and other displays as well as other types of operator interface. The objective is to encourage those who will design or use displays to consider at an early stage factors that can enhance the usefulness and operational success of these devices.

Marcus, Aaron (1983) "Graphic Design for Computer Graphics" IEEE Computer Graphics & Applications. Vol. 3, No. 4, p. 63-70.

From their very beginning, all computers were computer graphics systems. In other words, they communicated with human beings by some means of graphic display or activity -- communicated through flashing lights, the revolving reels of a tape drive, or the simple alphanumeric characters of a line printer. Today, however, the means for conveying information to a human being are much more complex. High-resolution displays can make use of sophisticated type fonts, three-dimensional structures, dynamic objects, and intricate color relationships.

Despite all of this increased capacity to display data, the same fundamental tasks lie before us that we as communicators have always faced: How can we attract people to information? How can we hold their attention? How can we facilitate their understanding of the information? How can we help people to remember what they have learned?

Communication between computers and people takes place in three "faces" of computers: outerfaces, interfaces, and innerfaces. Each of these faces consists of conceptual "frames" of communication that are embodied in specific displays on paper, film, or glass screens.

Marcus, Aaron (1982) "Designing the Face of an Interface" IEEE Computer Graphics and Applications. Vol. 2, Issue 1, p. 23-29.

...there is currently a lack of specific guidelines for designing interfaces. Some compilations have appeared, but they tend to be at too fine a level of detail. They concern themselves with factors of legibility and ergonomic efficiency while failing to address the overall graphic design strategies of the major components of an interface. The greatest need for guidelines is in matters of readability. What aspects of interfaces encourage people--who might have limited abilities, failing interest, antipathy towards computers--to use the systems? As computer systems reach ever wider audiences, the notion of attracting and holding a user's interest and attention will not seem so foreign a goal.

The discipline of graphic design can help to create and organize interfaces that have a high degree of efficiency, sophistication, and attractiveness. It is the aim of this article to acquaint the computer graphics community with graphic design and some of its relevant literature and to describe experimental changes made in one information management system on the basis of its principles.

Marcus, Aaron (1984) "Bibliography of Graphic Design for Computer Graphics" in Proceedings of the 5th Annual Conference & Exposition, Vol. 1 - Tutorials, National Computer Graphics Assoc.

For the benefit of the computer graphics community, Aaron Marcus and Associates (AM+A) has prepared an abbreviated list of useful references. The list is from a longer bibliography being prepared by AM+A. The current list contains examples and guidelines for the graphic design of signs (icons and symbols) and the design of screens (windows, borders, and templates). Some of the publications listed may not be familiar to programming community.

Marcus, Aaron (1984) "Corporate Identity for Iconic Interface Design: The Graphic Design Perspective" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Sessions, National Computer Graphics Assoc.

Because computer graphics displays are using more non-alphanumeric symbolism to facilitate human-computer communication, graphic design, a discipline concerned with systematic, information-oriented communication, is important in designing the "corporate identity" of the human-computer interface. Principles of applied visual semiotics can be used to critique and create these dialogues. Case studies of the Star, Lisa, and Metaform office automation systems are analyzed.

Marcus, Aaron (1984) "Graphic Design Issues in User Interface Design" in Proceedings of the 5th Annual Conference & Exposition, Vol. 1 - Tutorials, National Computer Graphics Assoc.

The tutorial will cover graphic design issues in user interface design. Subject areas include the following: screen layout, windows (borders, shapes, layouts), icons and other symbols, typography, color, animation (scroll, wipe, fade, pan, zoom), and movement. Factors of legibility, readability, and aesthetics will be discussed. The concepts of visual semiotics and interface corporate identity will be introduced. Similarities and differences of approach in several case studies will be examined.

McCormick, E. J. (1976) Human Factors in Engineering & Design, 4th Edition, McGraw-Hill.

McDonald, J. (1977) "Viewing CRT Displays" IEEE Conference Proceedings Displays for Man-Machine Systems, No. 15, p. 43-45.

Since the early days of radar it has been an ongoing requirement for operators to work in brighter environments. Today, using computer refreshed bright displays it is possible for some types of radar pictures to be viewed in normal office lighting whilst other types require a comparatively dim environment. Whichever of the two types is to be used it is necessary to achieve the best performance possible.

It is well known that a neutral density filter placed over a CRT will increase the luminance contrast of the display since light from the CRT data is attenuated only once whilst ambient illumination is attenuated twice. It is also known that a spectrally matching filter can increase contrast even further for a given luminance attenuation...However, by use of denser and denser filters the contrast may be increased although in the end the display will be useless since data luminance will be too low.

...The questions this paper sets out to answer are:

i) With what contrast and luminance are operators most efficent?
ii) What effect does colour separation make?

Two types of radar display have been considered:

a) A P31 (green) CRT display used in bright office type ambient lighting.
b) A P26 (amber) CRT display for displaying raw radar (p.p.i.) used in typically dim ambient lighting.

McNamee, Thomas (1985) "Screen Composure" PC Tech Journal, Vol. 3, No. 4, April 1985, p. 149-50.

Anyone who has ever designed data entry screens by laying them out on graph paper in an 80-by-25 grid will welcome a new class of utilities called display managers. Display managers do for screen design what word processors do for document composition. These tools enable users to design screens and to specify which fields are to receive user input and which are to display output. They allow the designer full control over display attributes, such as color, and offer automatic validation of input and formatting of output. Two of these utilities are reviewed here: IBM's new entry, theApplications Display Management System (ADMS), and Digital Research's (DR) Display Manager.

Meister, David & Dennis J. Sullivan (1969) "Guide to Human Engineering Design for Visual Displays" Defense Systems Division Bunker - Ramo Corp., Alexandria, VA, Aug. 1969.

This guide is intended to serve as a source of basic data for display engineers on human capabilites and performance as these relate to visual display characteristics. Its primary purpose is to acquaint visual display engineers with what is currently known about the relation between observer characteristics and various types of display applications. The reader is assumed to have a knowledge of the engineering fundamentals and scientific principles related to display design, hence no detailed discussion of these matters is provided.

Morse, Alan (1979) "Some Principles for the Effective Display of Data" Computer Graphics, 13, p. 94-101.

Since computers can produce output at a high rate, it is often useful for it to put that output in a form that facilitates human analysis. There has been much research on the human factors of displays; from this research, we can evolve principles to guide the effective display of computer output. The two main principles described here are the principle of proportional effect, which guides the encoding of a datum's identity and value, and the principle of least effort, which minimizes the effort needed to scan, and perceive and interpret the display. Some of these ideas are illustrated using data generated by a neural simulation. Key Words and Phrases: visual data encoding, human factors, computer graphics, effective data displays, visual load, display design principles.

Murrel, Hywel (1976) Men and Machines, Essential Psychology Series, Methuen, p. 65 "Special Displays".

...It is still unfortunately true that in spite of all the research which has been done by physicists and psychologists accidents at sea are still occurring with alarming frequency.... Research has been concentrated on problems associated with the detection of the radar echo or pip, but no one seems to have been very much concerned with what happens afterwards. Even now, many skippers distrust the information which they get from their radar and prefer to rely on their own visual observation (there is some legal backing for this), so that we do not yet know the answer to the very important psychological problem as to why when he should be able to see that he is on a collision course with another vessel, a skipper will persist in maintaining his bearing and speed until the inevitable occurs.

Myers, Ware (1980) Computer Graphics: The Human Interface. Computer. Vol. 13, No. 6, p. 45-54.

...These three--the secretary, logic desinger, and artist--are a sample of the people now using computer operated displays to do their own work. The systems differ widely and the users' understanding of the systems, as distinguished from their understanding of their own work, varies from a little to a lot. The challenge of meeting the needs of all kinds of users, ie., of how the sytem is to be interfaced to the human being, occupied a SIGGRAPH 79 panel discussion oraganized by Tom Bruggere of Tektronix.

Osga, G. A. (1984) "Legibility Study of a Tactical Graphics Language for High-Resolution Monochrome Display" SID 84 Digest, SID International Symposium , San Francisco, Calif.

The Human Engineering Branch of the Naval Ocean Systems Center (NOSC) was recently confronted with the problem of specifying a size and font style for graphics symbology used by the Naval Tactical Data System (NTDS). Two major factors created a need for systematic research to address this problem. First, there has been a recent trend for manufacturers and NOSC engineers to incorporate raster-scan displays into their designs of tactical consoles, as opposed to previous use of stroke-written displays. Second, a review of the literature showed that while guidelines for alphanumeric data were plentiful, there were no guidelines for creating raster graphics characters that could be applied to the Naval symbology. While there had been research addressing the problem of selecting discriminable graphics shapes, there had never been any research addressing the readability and font design of currently used stroke-written graphics. Increases in system capabilities increase the importance of optimizing symbol size, without compromising readability. As the number of symbols presented on a radar display increases, clutter problems will create readability problems due to overlap of symbols. If symbols are as small as possible, overlap problems will be reduced.

Peterson, David E. (1982) "Screen Design Guidelines" in Larson, James A., Tutorial: End User Facilities in the 1980's, IEEE Computer Society Press.

...First, we will discuss three types of dialogue. Two concern business data, and one is the menus and the prompts, and what I call "form," which is the image of an input form on a screen for the basic purpose of getting business data from the use into the application.

Secondly, we have information displays that take the business data out of the application and present it to the user, in feedback or in an inquiry program.

Finally, we will look at messages and replies, which are used both for application control and error recovery.

Porter, C. (1985) "Dimension and Depth (Large Screens)" Cameron Commun., Glasgow, Scotland, Syst. Int. (GB) Vol. 13, No. 5, 22-3 May 1985.

The increasing use of computer generated information, both graphics and text, has led to a growing need for large screen viewing facilities. A large screen is valuable in most cases where more than three or four people gather together to view the same information. A typical example is in

CAD/CAM where a large screen projector can give a far better impression of dimension and depth than the traditional 20 in. monitor. The user approaching the projector market will be met by a bewildering variety of products, claims and counter claims. This article attempts to identify the main criteria for selecting a projector and will assist in matching the correct projector to hardware and intended application. Descriptors: computer peripheral equipment; display instrumentation; equipment selection (computers); optical projectors. Identifiers: selection criteria; computer peripherals; displays; large screens; projector.

Reilly, Susan Smith & John W. Roach (1984) "Improved Visual Design for Graphics Display", IEEE Computer Graphics and Applications Vol 4, No. 2.

...Computer software programmers do not usually take visual design into account. Due to the programmers' lack of training in visual design techniques, a great need exists to recognize the importance of careful interface design and to modify software design methodology so that purposeful communication with the user is considered. To satisfy this need a wide range of expertise and research skill must be coordinated so that cross-fertilization can produce hybrid systems uniquely suited to specific problems.

Haber and Wilkinson, writing from a psychological perspective about the perceptual components of computer displays, suggest that a great strength of human vision is its capacity to encode multidimensional information rapidly. They also suggest that software be designed that allows the user to "see" multidimensional data as people do in real-life situations. We will use a broader conception of visual communication for designing computer displays, going beyond the concepts of perceptual psychology outlined by Haber and Wilkinson to include principles of design and composition found in fine art and advertising...

Schachter, Bruce J. (1981) "Computer Image Generation for Flight Simulation" IEEE Computer Graphics & Applications. Vol. 1, No. 4, Oct. 1981, p. 29-32, 58-68.

Flight simulators are devices in which air crews can train without the use of actual aircraft. In their most sophisticated form, they simulate an aircraft's instrumentation, vehicular motion and sounds, gravitational forces, radar and electrooptical sensor displays, and out-the-window views. The visual flight simulator is that part of the device which presents scenes for the pilot to view out the windows of the mock cockpit.

In early flight simulators, a visual invironment was created by movies or video produced by photographing model boards with servodriven television cameras (Figure 1). These approaches are limited in scope and cannot produce true perspective scenes from a wide range of viewpoints. Most modern simulators provide imagery generated by computer and are known as CIG--computer image generation--systems.

Shoji, K and Shogo Hayashi, (1984) "Echo Enhancement for a Marine Radar by New Display Techniques" Proceedings of the 1984 International Symposium of Noise and Clutter Rejection in Radars and Imaging Sensors, T. Musha,T. Suzuki and H. Ogura (Ed) IECE,1984.

Several new display techniques for the enhancement of radar echoes from ships, such as partial enlargement of the echo display in colour and monochromatic multi-tone and waterfall (3-dimensional) type display, have been investigated by the authors. It is demonstrated that these techniques are effective in giving valuable information on ship features and aspect for navigation use in quasi-real time.

Sims, Richard (1984) "Choosing a CRT Display" Design Engineering, Feb. 1984.

The cathode ray tube (CRT), as a media for displaying information, has been with us for many years...Despite the recent emergence of alternative display technologies such as LED (light emitting diode), LCD (liquid crystal display) and plasma panels, the CRT continues to remain the most cost-effective method of displaying high densities of information.

The starting point for any new produce development cycle must be the consideration of the user market and the task that the product is to perform. If we consider a portable microcomputer, for example, the system designer must consider the following points: a) Is the system truly portable? What is the weight and overall space envelope required by the display and will it have the capacity to operate from a low voltage dc source? b) What will the information format be? (ie. text, graphics or both). How many characters per row? How many rows? Upper or lower case, or both? c) Where will the system be used? Will it be used in the office or the home and in artificial or direct sunlight. d) How often will the sytem be used? Is it continually displaying the same information, constantly changing text or having periods of total shut-off.

Having considered these basic points, the system designer is now in a better position to consider the various key parameters in relation to monitor choice. These parameters are described in detail below.

Smith, Sidney L. & B. C. Duggar (1971) "Do Large Shared Displays Facilitate Group Effort?" in Engineering Psychology: Current Perspectives in Research, Appleton Century Crofts.

In man/machine information processing systems, information must be presented so that it can be perceived and interpreted by the human users. Reliance is generally placed on visual displays of one sort or another, and a decision must be made as to just how large such displays should be.

If a display is small in size, as small as a page in a book, or a sheet of paper in a typewriter, a viewer must be close to it to distinguish the details of the information it presents. It can be used by only one person at a time, or perhaps two. A larger display, such as a briefing chart, or a movie screen may be viewed by a group of people who use its information simultaneously. Because of these considerations, a design decision

concerning the appropriate size of displays, large or small, is often expressed as a choice between group or individual displays.
In terms of the possible value of large group displays, it has been argued that in situations where coordination of group effort is desirable, use of a common, shared display may facilitate system performance (Smith, 1962). Just how this might occur would preseumably depend upon the nature of the working group, its heirarchic structure, the nature of its common task, and the way in which the task is shared in terms of functional roles or jobs performed by the individual group members. The value of a group display, therefore, might differ from one setting to another...

Smith, Sidney (1971) "Visual Displays - Large & Small" in Howell, W.C. & Goldstein, I. L., Engineering Psychology. Current Perspective in Reasearch, p. 372.

Increasingly in the last several years we have heard much about the relative merits of group and individual displays, the reference being customarily to visual displays. A group display is one intended for common viewing by a group of individual people. As such there is nothing specified as to its physical size or other dimensional characteristics, which would presumably vary with each particular application--the size and seating arrangement of the group itself, and the amount and type of information which must be displayed.

Spannaus, T. W. & C. Pariseau (1985) "Screen Design for CAI" 26th ADCIS Conference Proceedings, Philadelphia, PA, 25-29 March 1985, p. 34-7.

To the learner, a CBT lesson really consists of the screens that he/she sees. As designers, we may not pay adequate attention to the design of screens, preferring to concentrate on the design of the whole lesson or even the course. It is essential that each screen be attractive, easy to understand, and instructionally effective. This paper provides general guidelines for the organization and layout of CBT screen based on educational psychology and the experience of typographers.

Stewart, T. F. M. (1976) "Display and the Software Interface" Applied Ergonomics, 7.3, 137-146.

This paper aims to provide designers with a framework to help them organise and apply ergonomics and human factors literature to the design of man-computer interfaces. The framework or classification is primarily concerned with the software interface and its use is illustrated in some human factors recommendations for the design of displays.

Streveler, D.J, and A.I.Wasserman (1985) "Quantitative measures of the spatial properties of screen designs" In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

This paper proposes certain quantitative measures for analyzing the spatial properties of screen designs and for designing experiments aimed at determining otimal values for the measures. The measures result from the application of three analytic techniques termed boxing analysis, hot-spot analysis and alignment analysis.

Streveler, Dennis J. & Peter B. Harrison (1984) "Measuring the 'Goodness' of Screen Designs" Hawaii International Conference on System Sciences, Computer Net Subconference (7th, 1984: Honolulu, Hawaii) Padunch ewit, Ittipon.

Methods of measuring the "goodness" of the syntactical properties of a CRT screen design are presented. These methods include Boxing Analysis, Hot Spot Analysis and Loading Analysis. An example from clinical medicine, the reporting of laboratory results, is used to demonstrate these methods.

Sweeters, W. G. (1985) "Screen Design Guidelines" 26th ADCIS Conference Proceedings, Philadelphia, PA, 25-29 March 1985, p. 42-5.

Every CAI author is involved with the issues of screen design. This paper presents specific guidelines concerning the use of space, text, graphics, color, lesson control, and lesson orientation. These guidelines can be used as a starting point for instructional designers wishing to develop their own screen design standards.

Tamura. H. and N Takematsu (1985) " Legibility of the VDT required for high performance task". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

This paper proposes an experimental method to evaluate legibility of the display and efficacy of the pointing device, to be applied to compare human performance both at VDT and paper-pencil systems. The result confirmed the performance is still considerably low compared to the paper-pencil system. The difference is larger for the task of the higher work load. The measure of performance defined in this paper may be used as the objective of improving devices.

Tullis, Thomas S. (1981) "An Evaluation of Alphanumeric, Graphic & Color Information Displays" Human Factors, 23(5), 541-550.

Four different types of CRT display formats were evaluated in the context of a computer-based telephone line testing system. The formats considered were narrative, which used complete words and phrases; structured, which used a tabular format; black-and-white graphics, which used a schematic of the telephone line; and color graphics, which also used a schematic but added color coding. The evaluation measured speed and accuracy of the subjects' interpretation of the displays of test results. Accuracy did not significantly vary with format but speed did. Response times for both graphic formats were consistently shorter than those for the narrative format. With additional practice, however, reponse times for the structured format were just as short. There was no significant difference between response times for the black-and-white graphic and color graphic formats.

Zuckerman, Mathew M. (1984) "Innovative Display Technologies - Why a Flat Panel When You Can Have A CRT? IEEE Computer Graphics and Applications, Vol. 4, No. 4.

Flat panel displays are finding use in electronic data processing equipment because they offer the advantages of reduced size and weight. Research in flat panels over the last 20 years has resulted in five flat panel technologies that are or will soon be commercially available to designers. The most promising flat panels in terms of cost and performance are based on conventional and bistable liquid crystal technology.

The obvious answer to "Why a flat panel when you can have a CRT?" is "for reduced bulk." The less obvious answers are improved transportability and ergonomics, considerations that are rapidly becoming exceedingly important to users of electronic data processing equipment. Personal computer users don't want to put their PCs on pedestals to be admired; they want to move and interact with them.

Documentation

Brown, Maxine D. "Pictures In/Pictures Out: Designing How-To-Draw Educational Materials" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Session, National Computer Graphics Assoc. 1984.

Productivity gains are measured by the benefits derived from using computer generated picutres in presentations, publications and decision-making. Productivity is also measured by the ease-of-use and cost/performance of computer graphics equipment. To maximize product use and effectiveness, the technical literature needs to meaningfully communicate the capabilities of the equipment to the end-user. And, what better way, than through the instructive use of pictures?!! Just as art books teach students how to draw by example, technical documentaion should teach end-users how to use hardware capabilities or software commands through the creative and effective use of pictures. Pictures in, pictures out... in a timely, efficient, accurate, easy way.

Clement, Darlene(1985) " Empirical Guidelines and a Model for Writing Computer Documentation". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

A model of the computer manual comprehension task is proposed in which four processes operate simultaneously: task-mapping of the structure of regular procedures onto the structure of computer commands, constructing a mental model of the computer system, inducing the command language grammar, and learning the structure of computer procedures. Findings from a study of five novices' comprehension problems with UNIX documentation are analyzed in terms of these four processes. The model and the findings from the study yield general heuristics and specific recommendations for document developers.

Katzin, Emanuel (1984), How to Write a Really Good User's Manual, Van Nostrand Reinhold Co., New York, 1984.

Smolensky, Paul, M.L.Monty and E.Conway (1985) "Formalizing Task descriptions for command specification and documentation".In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

We consider the problem of formally describing computer tasks not in terms of procedures that will accomplish them but rather in terms of the input given and the output desired. A feasibility study in the domain of printing suggests that task attributes provide a powerful language for such descriptions. We describe the constraints such attributes must satisfy, and the procedure we used to design the printing attributes and test their usability. Applications to attribute-oriented interfaces and documentation are discussed. It is argued that task description is important for moving the centre of human-machine interface design away from the machine and towards the user.

Watt, John,(1985) " High Street Marketing Requires Good Systems Documentation." Computer Magazine (GB) Vol.23, Issue 19, Jan 1985, p23.

Introduction: If some computer manufacturers expect to sell computers as they would washing machines, then they should not expect to get by with poor documentation. With shoddy documentaation the whole concept of buying computers from high street stores is an utter waste of time. As has been pointed out many times, it's not as if we just take it home and plug it in; it's got to undergo some complex installation procedures before it can even be beneficially used.......................

Weiss, Edmond H. (1985), How to write a Usable User Manual, ISI Press, Philadelphia, 1985.

Ergonomics

Barry, Steven H. (1984) "Requirements for Future Work Stations" SPIE Proceedings, Vol 457, Advances in Display Technology IV, The International Society for Optical Engineering, P. 100-105.

Cathode Ray Tube technology is mature. And, as we all know, maturity has its good and bad points. First the good points: The cost of CRTs is low, performance is high, their design is well understood, manufacturing facilities are well established, and their use is ubiquitous - leading to economies of scale in their mass production. On the other hand, less mature technologies are at hand whose advantages for some of today's applications cannot be met by CRTs. Thus, CRT engineers and work station designers who work with CRTs face significant new challenges based on the changing uses and users of advanced systems. Today, I will focus on some of the changes taking place in display use and discuss some engineering criteria that can be applied to satisfying new needs. Make no mistake about it, the criteria I suggest to you will tax the foreseeable state of the art.

Bernhard, A. (1984) "A Different Kind of Standard (Computer Graphics Ergonomics)" Computer Graphics '84, Proceedings of The International Conference, London, England, Oct. 1984.

Dainoff, Marvin J. (1982) "Occupational Stress Factors in visual Display Terminal (VDT) Opeeration: A Review of Empirical Research", Behavior & Information Technology, Vol. 1, No. 2, 141-176.

A review of the literature involving empirical research (experimental and field investigations) on stressful aspects of visual display terminal (VDT) operation is presented. Studies reviewed included assessment of visual fatigue and/or perforamnce, musculoskeletal symptoms and operator attitudes towards job demands and quality of working life. In adddition, some investigation included discussions and evaluations of the physical attributes of VDT workplaces; including ergonomic factors..., environmental factors...,and psychosocial factors.. The literature reveals that levels of visual and musculoskeletal complaints among VDT operators are high. Moreover, ergonomic field assessment of VDT workplaces indicate that the majority of those examined were suboptimal with respect to existing recommendations regarding lighting, glare control and anthropometric dimensions of screen, keyboard, desk and chair. Nevertheless, evidence of causal linkages between specific ergonomic attributes of the workplace and specific patterns of symptomatology are lacking.

Finally, work demand and task structure attributes to the VDT operation were demonstrated to have strong effects on incidences of reports of visual and postural symptoms as well as on psychosocial attitudinal indicators. Hence, it is argued that approaches toward stress reduction must include job content as well as ergonomic factors.

Grandjean, E. & E. Vigliani (1982) Ergonomic Aspects of Visual Display Terminals, Taylor & Francis Ltd., London.

Konz, Stephan (1979) "Endurance and Rest for Work with Concentration and Attention" in Proceedings of the Human Factors Society - 23rd Annual Meeting.

Although determination of the proper fatigue allowance is of interest, job design is more important so fatigue effects are reduced. Avoid pace work. Night work and repetitive work -- especially for socially isolated workers -- seems to cause faatigue. Short breaks often seems better than long breaks occasionally. Passive rest is not as good as working and active rest.

...This paper will deal with category six (strain due to concentration and attention). The paper will be divided into five sections: 1) criterial to be used, 2) variables affecting concentration and attention, 3) timing and length of rest, 4) types of rest, and 5) summary.

Lynch, Gene (1984) "Here's Look'n at and Work'n with you, Kid!" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Sessions, National Computer Graphics Assoc.

This paper gives guidance in the ergonomic evaluation of computer graphics systems. There are two schools of thought when it comes to user interfaces: the productivity school and the user well-being school. The interaction between productivity and user well-being is not yet well understood. The user interface is examined from the perspective of its physical, perceptual and cognitive components. Each of these factors contributes to both productivity and user well-being, and to each by different mechanisms. Fianlly, a structure of weighting factors is proposed as a process for developing metrics to be used in comparisons of user interfaces. These metrics could also be employed in clarifying the relationship between productivity and user well-being. There is a call for research on all levels to refine the structure and improve the weighting factors.

Mackworth, N. H. (1961) "Researches on the Measurement of Human Performance" in H. Wallace Sinaiko, Selected Papers on Human Factors in the Design and Use of Control Systems, Dove Publications Inc., New York.

Matula, Richard A. (1981) "Effects of Visual Display Units on the Eyes: A Bibliography (1972 - 1980)" Human Factors, 23(5), 581 - 586.

Visual display units (VDUs) have been reported to cause such eye difficulties as eyestrain, visual discomfort, and visual fatigue. In addition, there are effects on visual accommodation as well as effects arising from contrast and glare sensitivity. This bibliography brings together in one place the widely dispersed literature on the effects of

VDUs on the eyes.

Mourant, Ronald R., Raman Lakshmanan and Roengrojn Chantadisal (1981) "Visual Fatigue and Cathode Ray Tube Display Terminals" Human Factors 23(5) 529 - 540.

Study I investigated the effects of display type, amount of information presented, and display contrast on the visual mechanism during a visual search task. In the first phase, two subjects performed the visual task for four 3-h sessions. In the second phase, subjects were tested for two 6-h sessions. CRT usage for 3 h produced measurable visual fatigue in the eye movement and/or accommodation mechanism, as measured by increased durations to move from a near point and focus on a far point (and vice versa). Such visual fatigue was not present in the hard-copy visual search task.

In a second study, subjects performed the visual task for two 4-h sessions. Two h of CRT usage produced measurable fatigue in the eye accommodation mechanism as well as an increased blink rate. Such visual fatigue was also present in the the hard-copy task but to a lesser extent. In both studies, 1-h breaks produced a marked reduction in visual fatigue indices.

Myers, Ware (1984) "The Ergonomics of Video Display Terminals" IEEE Computer Graphics & Applications 4(1), p. 7 - 15.

It looks like everybody from the operators to the Naitonal Institute for Occupational Safety and Health is concerned about the effects of video display terminals on the well-being of the users. Still, is the situation as bad as these observers imply? After all, many people in computer graphics spend long hours in front of cathode-ray-tube displays without noticing adverse effects. And millions of ordinary citizens spend an average of six hours a day in front of their television sets -- essentially the same technology as VDTs -- without evident harm. At the same time, thousands of terminal operators are experiencing various types of discomfort.

Is it possible to get at the truth about VDT hazards, or does the apparent truth depend upon each observer's vantage point? In this article I hope to clarify the issue by looking first at the possibility of radiation hazards, then at eye problems, and finally at the matter of muscular pains. Since various members of the computer graphics community design video display systems, arrange workstation layouts, use the displays themselves, or promote their use to other communities of users, they have a "need to know."

Plott, Herman H. Jr., J. David Irwin & Lewis J. Pinson (1975) "A Real-Time Stereoscopic Small-Computer Graphics Display System." IEEE Transactions on Systems, Man & Cybernetics Vol. SMC - 5 No. 5, Sept. 1975.

A brief review of the principles of steroscopy is given followed by a discussion of candidate methods for providing stereoscopic viewing of display data. An analog computer implementation of a stereoscopic graphics display system is described. The analog implementation provides real-time display capability but has no data storage capability. Implementation with a small digital computer provides data storage but is significantly slower for displaying dynamic changes in the data. Other points of comparison between the two systems are given with the conclusion that a hybrid system would combine good features of both. Experimental evaluation relative to eye fatigue is given for three specific viewing techniques. Example stereograms are given for both the digital and analog systems. Of particular interest was application of the display system for viewing biomedical data, as illustrated by an example display of a vectorcardiogram.

Quiring, Susan M. (1984) "Task Performance and Perceived Glare Under Varying Incandescent Task Lighting Conditions on the Microcomputer Screen." Kansas State University Dissertation Abstracts International Dec. 1984, Vol. 45(6-A) p. 1612.

The microcomputer screen (VDU) is a vertical surface that is best viewed under low illumination levels. This study examined five incandescent task lighting conditions that provided the recommended 50 to 70 fc illumination on the paper task yet allowed adequate contrast on the VDU.

Specifically, the research determined differences between a semi-direct diffused lamp with slightly slanted opaque shade located in the same plane with 1) the VDU and 2) the subject; and a direct, nondiffused lamp with funnel-shaped opaque shade in the same plane with 3) the VDU, 4) the subject, angled toward the paper task, and 5) at a 45 degree angle, off-shoulder the subject, pointed toward the paper task.

The researcher also investigated differential effects of glasses and posture change, and identified demographic characteristics.

...The recommended study lamp, semi-direct diffused with slightly slanted, neutral-colored opaque shade, with bottom edge located at eye level and next to the VDU is an effective choice for these tasks. Placing the VDU and paper task at consistent viewing angles and at recommended heights, and having a flexible task light should minimize bifocal problems.

Raftery, Catherine & John Keener (1982) "Providing Terminal Comfort" in Larson, James A. Tutorial: End-User Facilities in the 1980's IEEE Computer Society Press.

It has been said that when it comes to finding tools and appliances that are easy to use, nobody has to search longer than a left-hander. There is another larger group, however, that may have an even more valid claim on the title of "Forgotten Consumer." Anyone whose physical proportions and capacities are not quite average has occasionally experienced the discomfort of working with implements that are not quite right. Why? They were engineered for the "average" user -- that special breed who is not nearly as numerous as designers have believed. Only recently have developers and manufacturers of computer equipment -- especially CRT terminals -- begun to realize that if their product is to used by a variety of operators, it must be adjustable to each individual.

Smith, Michael J. (1984) "Human Factors Issues in VDT Use: Environmental & Workstation Design Considerations" IEEE Computer Graphics & Applications, Vol. 4, No. 11.

The increased use of video display terminals for general office applications such as data entry/retrieval and work processing has brought to light human factors problems associateed with VDT use. These problems are epitomized by the complaints of VDT users about visual and musculoskeletal strain and discomfort. A number of studies have been conducted in field settings and in laboratory simulations to determine the causes of these complaints. Human factors considerations regarding environmental and workstation design ahave been shown to be significant determinants of the quantity and quality of visual and muscular complaints in VDT operators. This article reviews research that has examined these human factors considerations.

Smith, Michael J., et al., (1981) "An Investigation of Health Complaints & Job Stress in Video Display Operations" Human Factors, Vol. 23(4), p. 387-400.

A questionnaire survey dealing with working conditions, job stress factors, health complaints, and psychological mood state was filled out by approximately 250 video display terminal (VDT) operators and 150 nonoperator control subjects at five participating work sites. Clerical VDT operators reported higher levels of job stress and health complaints but little difference in psychological mood state than did professional VDT operators and the control subjects. The job stressors showing the greatest impact on the clerical operators dealt with workload, workpace, lack of control over job activities, boredom, and concerns about career development. The health complaints that showed the greatest differences between the groups dealt with visual, musculoskeletal, and emotional helath problems. The results indicate that job content factors and VDT use interact to contribute to VDT operator problems.

Smith, Wanda (1984) "Control of Screen Glare" SPIE Proceedings, Vol. 457, Advances in Display Technology IV, The International Society for Optical Engineering, p. 2-6.

This paper describes the perceptual and physical ergonomic problems inherent in attempting to control glare created by reflections on computer display screens. Several commonly used techniques to control glare are described, including their advantages and disadvantages. Methods to solve this problem through environmental and display housing design are discussed. The effects of glare control treatments on visual discomfort, operator performance, image quality and operator preferences are presented. Finally, the requirements of special applications are listed to demonstrate the need for continued research to solve ot only the current problems with glare, but those of the future as well.

Smith, Wanda J., (1979) "A Review of Literature Relating to Visual Fatigue" in Proceedings of the Human Factors Society - 23rd Annual Meeting.

The design of workstations with visual displays has become the subject of considerable interest and concern during the past few years. One area of concern relates to the assumption that long term viewing of such displays at close focal distances may contribute to visual fatigue. A second is the effect on the human visual system of the frequent changes in surface illumination associated with display units used in combination with hard copy documents. As a consequence of these and other concerns, the popular press has published articles that have aroused the interest of various scientific organizations regarding the subject of these effects. This paper discusses a review of some of the literature regarding a limited aspect of this issue, namely the accommodation and pupillary systems as they relate to long term viewing of visual display units.

Snyder (1983) "Optimizing the Equipment and Operator" Proceedings of Health & Ergonomics Considerations for Visual Display Units. American Industrial Hygiene Association. Akron, Ohio, p. 21-28.

Stammerjohn, Lambert W., et al. (1981) " Evaluation of Workstation Design Factors in VDT Operations, Human Factors. 23(4), 401-412.

An onsite evaluation was conducted at five establishments using VDTs to examine VDT workstation designs and to compare these designs to recommendations obtained from the literature. Measurements were made of such critical design factors as keyboard height, screen height, workstation illuminaton, and glare. Illumination levels were generally in the 500 to 700 lx range, and questionnaire data confirmed that these levels were acceptable to most employees. A number of design problems were found in the VDT workstations, including excessive keyboard heights and screen positioning which would require excessive inclination of the head and neck for screen viewing. A majority of the operators surveyed found a number of factors to be bothersome, including screen readability, refected glare, screen brightness, and flicker. A number of the dissatisfaction parameters were found to be related to levels of somatic (health) complaints.

Thackray, Richard I., R. Mark Touchstone, (1982) "Performance of 40-to-50 Year Old Subjects on a Radar Monitoring TAsk: The Effects of Wearing Bifocal Galsses & Interpolated Rest Periods on Target Detection Time" Civil Aeromedical Research Institute, Oklahoma City, OK, April 1982.

The present study examined the effects of wearing bifocal glasses and interpolated rest periods on the performance of 40-to-50 year-old subjects on a radar monitoring task. The visual display was designed to resemble an air traffic control radar display containing computer-generated alphanumeric symbols. Forty men and women were divided into four equal-sized groups, with each group consisting of one of the four possible combinations of bifocal/no-bifocal and rest/no-rest conditions. All subjects were tested over a 2 hour session. Rest periods (a 5 minute break every 30 minute) significantly reduced the performance decrement of 40-to-50 year-old subjects, bringing performance to a level approximating that of 18-to-29 year old subjects without rest periods. The wearing of bifocal glasses did not contribute to visual strain or somatic discomfort.

Expert Systems

Cooper, M.B. and A.L. Kidd,(1985)"A man-machine interface for an expert system". British Telecom Journal (GB) vol.3, No.1,1985p112-115.

The authors discuss the man-machine interface (MMI) issues arising from the development and use of a prospector-type expert system shell. Implications for designing good MMI for future expert systems are discussed.

Johannsen, G., J.E. Rijnsdorp, and A.P. Sage (1983) "Human System Interface Concerns in Support System Design". Automatica Vol.19, No.6, Nov 1983, p 595-603.

Man-machine systems exhibit some sort of functional synthesis between humans and machines. Such systems range from elementary interaction to the capabilitieis of machines, the human interface issues become more important. Models of the components of human behaviour as they relate to machine interfaces can contribute to knowledge in the area. That, combined with the history of interface design, indicates some of the areas which need more research.

Kidd, A.L. (1983) "Human Factors in Expert Systems" in Coombes, K (ed), Proceedings of the Ergonomics Society's Conference, 1983. International Publications Service, Taylor & Francis, Inc, N.Y.

The development of expert or intelligent knowledge-based systems is raising some new and very important human factors issues in the field of man-computer interaction. With the advent of thinking, reasoning systems, the cognitive characteristics of the human mind must become a critical design constraint in the production of such systems. This paper attempts to identify the major research questions in this area.

Kidd, A.L. (1985) " Human Factors in Expert Systems". Data Processing Vol 27, No.4, May 1985, p.15-17.

Expert systems outside the laboratory environment have few successful installations. Part of the problem lies in designing of the system toward an isolated problem instead of expecting the system to serve as a consultant as well. Problem areas of design and use include eliciting and representing knowledge and user interface design. Redesigning the user interface would hopefully rectify the rigid yes/no questions and create a dialog which may include graphics interface and more flexible access to the system's knowledge.

McCune, B.P. and Drazovich, R.J. (1983) "Radar with Sight and Knowledge" Def. Electron. (USA) Vol.15, No.8. Aug,1983.

Using an artificial intelligence knowledge base to drive the processing of sensor images, a radar target classification system recognizes what it sees.

Pisano,A.D. and H.L.Jones (1984)," An expert system approach to adaptive tactical navigation".IEEE First Conference on Artificial Intelligence Applications (Cat.No. 84CH2107-1) IEEE Comput. Soc. Press,1984.

A knowledge-based approach to managing the navigation sensors on advanced tactical aircraft is presented. The resulting system, called the Expert Navigator, makes critical equipment and mission decisions from an aircraft's perspective. Such a system must deal with real-world sensory data, monitor a plane based on those data, and be exceedingly reliable. As such, the Expert Navigator requires an extraordinary depth of knowledge about navigation and must be capable of reacting to asynchronous events as circumstances change or components fail. The details of the Expert Navigator are discussed along with a demonstration test-bed that couples the navigator to a high-fidelity simulation of the aircraft.

Rojaram, N.S. and H. Tsehaie (1985)" Expert Systems: can they help prevent disasters? (industrial safety)". In Tech (USA) vol.32,no.12,1985, p41-3.

Industrial equipment -machinery and vessels as well as controls- is configured as series of man-machine systems. Given sufficient time, access to information, and a relaxed atmosphere , most humans are capable of making sound decisions. However, none of these prerequisites is likely to be present during the emergency situations in which they are most needed. Expert systems, a technology derived from applied artificial intelligence, may provide a means of minimizing human error and mitigating its possible consequences.

Schkade, L.L.,C.W. Slinkman and M.E. Eakin, " Some psychophysiological considerations for the design and use of expert systems" In Proceedings of the Eighteenth Hawaii International Conference on System Sciences 1985 vol. 1, 609-14. Gallizzi, E.L. et al. (Eds). Hawaii Int, Conf . on Syst. Sci.,1985.

An experimental study of electroencephalographic (EEG) patterns, as reflections of brain activity, in relation to cognitive style measures, as indicators of mind functioning, provides results with implications for the design and use of expert systems. The dominant preference for using spatial relationships in internal logical functioning by some individuals suggests the need for research on new approaches for the development of expert systems.

Smith, S. and R. Lane,(1984) "An intelligent operator aid for dynamic route planning". Offshore Computers Conference, SCICON, Ltd., London, England,1984.

Considers an application of decision aiding for maritime operations, viz. the design of an intelligent operator aid for dynamic route planning. The limitations of existing methods are identified and an AI approach is proposed that combines algorithmic and heuristic processing elements within an embedded system. The advantages of this approach are described in terms of operational acceptance and further applications are discussed briefly.

Weiss, Sholom M. and C.A. Kulikowski (1984) A Practical Guide to Designing Expert Systems. Rowman and Allanheld, 1984.

Maps

Byrne, Holly & Ronald Summars (1975) "The Selection of Color for the USSR Agricultural Atlas" Auto Carto II, Proceedings of the International Symposium on Cartography and Computing: Applications p. 267-294.

Color-coding, that is, the assignment of colors to things represented on a map, is a complex process and a very important ingredient in map deisgn. The success of map could very well depend on the proper use of color. Using color requires, among other things, a good judgment and a "feel" for color and there are many differences of opinion, even by those with extensive training and experience.

Many questions confront the cartographer when using colors, such as, "Do I use colors just to make the maps more attractive regardless of whether it can be as effective with fewer colors?" The objective of the map should surely have an influence on the answer to whether color should be employed, but the use of process colors, i.e., the use of combinations of only a few basic colors to produce a wide range of tones, will more readily allow one to answer such a question in the affirmative.

Carel, W. L., M. L. Hershberger, J.A. Herman, J. J. McGrath (1979) "Design Criteria For Airborne Map Displays Vol. II: Design Criteria" Hughes Aircraft Co. Proceedings of Human Factors Soc., 23rd Annual Meeting, p. 79.

This is the final report of research conducted under ONR Contract ... The work accomplished is reported in 2 volumes. Volume 1 describes the methods used to develop the design criteria and the results of the surveys, analyses, and experimental reseearch conducted in the course of the program. Volume 2 consists of the statement of the design criteria.

The research reported in Volume 1 is categorized under the following headings: 1) Mission Requirements Analysis, 2) The Legibility Problem, 3) A Survey of Contemporary Map Displays, 4) A Survey of Users of

Operational Map Displays, and 5) A Survey of Contemporary Cartographic Support Systems.

The criteria described in Volume 2 are grouped under two main headings: 1) The Displayed Map Image and 2) Other Design Issues. Criteria appropriate to the displayed map image were developed from operational requirements and from legibility requirements. Criteria appropriate to other design issues deal with features of map displays that are not directly related to the displayed map image; ie., operating modes, controls, updating, and the like.

Carter, James R. (1980) "The Cartographic Potential of Low-Cost Color Computer Graphics Systems" Auto Carto IV, Proceedings of the International Symposium on Cartography and Computing: Applications in Health & Environment, Vol. II, American Congress on Surveying and Mapping.

For most cartographers the direct view storage tube (DVST), as in the Tektronix 4010 family of terminals, is the basic unit of graphic display. The storage tube displays only monochromatic vectors and shades or tones can only be created by drawing patterns of lines. The resolution of these tubes is usually 760 by 1024 addressable positions which has become accepted as the standard of graphics quality. Because the screen displays everything written on it, a display cannot be erased selectively. Displays can be documented with hardcopies using special photocopiers or plotters. A variety of storage tube systems are now available from simple terminals to integrated graphic system with multiple work stations. Prices range from $4,000 upward into six figures. A sizeable body of software is available, including many mapping programs and subroutines.

Cuff, David J. (1975) "Conflicting Goals in Choosing Colors for Quantitative Maps" Auto Carto II, Proceedings of the International Syumposium on Cartography and Computing: Applications p. 267-294.

In choosing colors for a map or series of maps it is essential to first identify the purpose of the color scheme, and second to be aware of the three dimensions of color (hue, darkness, and intensity) and how they can be used to accomplish that purpose.

An important distinction to make is between the use of colors for qualitative differences versus using colors to symbolize quantitative differences between map areas. This discussion will focus on colors used for quantitative differentiation conflict. (Minor goals may be identified tentatively as follows: equal-appearing intervals, hues appropriate to the theme being mapped, and variety in colors from one map to the next.)

Dalton, J., J. Billingsley, J. Quann, P. Bracken (1979) "Interactive Color Map Displays of Domestic Information" ACM/Siggraph '79, Computer Graphics. Vol. 13, No. 2, p. 226-233.

...This paper discusses the operation of the Domestic Information Display System, presents sample output products, and describes in detail the software and hardware organization through which the system flexibility and rapid response were achieved. Key Words and Phrases: interactive computer graphics, color raster displays computer cartography, geographic displays.

Dobson, M. W. (1975) "The Map--- In the Mind's Eye" Proceedings of the International Symposium on Computer-Assisted Cartography, Auto Carto II, U.S. Dept. of Commerce, American Congress on Survey and Mapping, Sept. 1975, p. 225-237.

The thematic map seems to be a whole that is more important than the sum of its parts. The major body of research that has been conducted over the past half century, however, has dealt with variables related to a map's elements rather than to the information-carrying capacity of the cartographic device. Quite obviously the study of maps is the study of complexes, structures, interactions, and grammars and the most interesting, and at the same time the most neglected, problem is that of map induction particularly hypothesis formation, learning, and concept attainment on the part of the map reader. Although many cartographic studies have been aimed in the direction of these factors they have usually stopped short of the central point which is that perception basically turns raw and unstructured sensed data into coherent wholes.

Granda, Thomas M. "A Comparison Between a Standard Map & a Reduced Detail Map within a Simulated Tactical Operations System (SIMTOS)" U.S. Army Research Institue Techincal Paper 274, Essex Corp., Alexandria, VA, June '76.

The use of reduced maps in place of standard Army maps has often been recommended for the upper command (e.g., division) levels. Within the context of a simulated tactical operations system, several variables that were thought most likely to be affected by the use of reduced detail maps or echelon information needs were observed in an offensive planning phase and an offensive combat phase. Among the dependent variables included were number of data frames accessed, time to access data frames, and combat effectiveness scores.

The analyses of variance performed on the variables show significant main effects for the echelon factor for the amount and type of information accessed, and for one combat effectiveness score. No significant difference in performance during planning or combat was associated with the level of map detail factor. Therefore, the feasibility of using reduced detail maps in conjunction with a computerized graphic display capability should be investigated.

Infante, Carlo (1980) "Display Technologies in Computer Aided Applications", Auto Carto IV: in Proceedings of the International Symposium on Cartography & Computing: Applications in Health & Environment, Vol. 1, American Congress on Surveying & Mapping, p. 33-39.

The pervasiveness of the computer in the modern world is a truism. It is hard to think of an important activity such as business administration, scientific investigation, engineering design, office information flow or even home management in which the computer does not play an essential role. The reason for this state of affairs has been ascribed to the explosion of solid state technology which has made possible circuits of increasing complexity at ever diminishing sizes and costs. While this is for the most part true, there has been an accompanying explosion of display technology, which has allowed ever increasing sophistication in the manner in which computerized information can be accessed by human beings. In this paper an assessment of the state of Display Technology will be made.

Kaufman, Lloyd (1975) "The Uses of Color" Auto Carto II. Proceedings of the International Symposium on Cartography & Computing: Applications p. 267-294.

...The map, by virtue of its pictorial properties, allows the observer to process information in parallel and in rapid sequence and relate it quite directly to meaningful categories of knowledge... However...there is little point in transmitting a large amount of information per unit time if the receiver is incapable of handling it. While it may be possible to represent many different dimensions simultaneously in a single map, we can reach a limit beyond which the human map reader will become confused. Thus, the scientific study of the human as an information processor is quite pertinent ot the task of the mapmaker who wants to transmit as much information to the mapreader as can be conveniently handled. To do this he must take into account the amount of time that the reader has available to study the map, the way in which the information is to be represented, e.g., in alpha-numeric form or in terms of coded shapes, the legibility of the elements of the map, the purpose for which the map is intended, and so forth. My main focus in this talk is on color as a means for providing information in maps. Thus, color, as you all know, can be used to replace or supplement alpha-numeric symbols. It is obvious to all of us that such a use of color can have important effects on the rate at which information is communicated to the reader. There must, of course, be a trade-off between the value inhering in the use of color and the economics of color reproduction. I shall...deal... with the idea that a better understanding of how the human being senses and uses color can enhance the effectiveness of the application of color in mapmaking.

McCleary, George F. Jr. (1975) "In Pursuit of the Map User" Proceedings of the International Symposium on Computer-Assisted Cartography, Auto-Carto II, U.S. Dept. of Commerce, American Congress on Survey and Mapping, Sept. 1975, p. 238-250.

Man's uses of maps are highly varied. Some are simple -- a simple locational map for a familiar environment is a good example (it serves superfluously as a navigational device, and might be better assayed as an advertisement). Others are exceedingly complex -- examples are numerous, the best probably being reference maps which present masses of data for visual integration and correlation. Some operations and activities depend for their success directly on effective map use; in other situations the role of the map is subtle, but no less critical. While many maps are created every year, there has been too little evaluation of their use and effectiveness. Further, many maps seem to have been developed without real understanding or concern for the map user. The focus of this paper is on the map user, first, with concern for the man-map behavioral system and, second, with several suggestions about research which might help us understand the map user better. For the cartographer, either as a producer or a researcher, the principal issue is that the map user will be reading the maps which have been prepared for him.

Moellering, Harold (1980) " Strategies of Real-Time Cartography", Auto Carto IV: Proceedings of the International Symposium on Cartography & Computing: Application in Health & Environment, Vol. 1, American Congress on Surveying & Mapping, p. 278-287.

Machine oriented numerical cartography in recent years has seen interesting and exciting developments in numerical algorithms, data structure, interactive systems design, man-machine communication and hardware devices which have been utilized in analytical, display and production settings. These prodigious efforts, not unsurprisingly, have resulted in a number of new cartographic products which go far beyond the conventional definition of what constitutes a map. This paper provides a conceptual structure for these standard and new cartographic products by further developing the idea of real and virtual maps, and showing that many cartographic operations are really transformations between states and such maps. This notion of real and virtual maps fits neatly into the existing cartographic communication concepts which can be made much more powerful on an operational basis by interactive (Moellering, 1977) and real-time cartographic systems. The strategies of use of virtual and real map transformations are related to the kinds of cartographic tasks to be done with an emphasis on recent work by the author on dynamic spatiotemporal cartographic displays.

Morrison, Joel L. (1980) "The Benefits of Computer Assisted Cartography for Map Reading" Auto Carto IV: Proceedings of the International Symposium on Cartography & Computing: Applications in Health & Environment, Vol. 1, American Congress on Surveying Mapping, p. 496-503.

It may be maintained by some that a discussion of the benefits of computer assisted cartography for map reading is premature, and in fact, it may correctly be pointed out that the testing by cartographers of map reading abilities on computer produced maps has not even begun as yet in a systematic way. This state of affairs is especially true of the testing of map reading abilities on 'temporary maps' appearing on CRTs. On the other hand, some may maintain that the benefits for map reading of computer assisted production environments are obvious and that it is not necessary to take the time to call attention to them.

The intent of this paper is to attempt to direct our thinking about map reading in a computer assisted environment. It is now an appropriate time to proceed to a more detailed level in the evaluation of the use of computer assistance in cartography. The technological revolution in cartography, which computer assistance represents is no longer in its infancy; although it continues at a fairly rapid pace. The beginning phase of the revolution is past and the results will be part of the technology of the discipline of cartography for years to come.

Moses, Franklin L., Richard E. (1979) "User Performance Under Several Automated Approaches to Changing Displayed Maps" U.S. Army Research Institute for the Behavioral & Social Sciences Technical Paper 366, Alexandria, VA, June 1979.

Performance in a route selection task was used to evaluate automated methods for changing from one displayed segment of a map to another. Participants were 24 Army officers, who chose successive 6.75 x 9 km map segments (1:50,000 scale) for solving 12 problems. Each problem requested the fastest road route between pairs of cities within a 60 x 81 km region. Participants solved problems by electronically marking road routes across map segments. Methods for changing map segments were a) continuous map scanning and b) discrete map segments using three different amounts of border overlap (0%, 25% and 50%). Results showed that different map change conditions did not significantly affect the quality of routes chosen. The least time for problem solutions occurred when map segments with 50% overlap were used, although 25% overlap produced similar data. Designers of map display systems for the military could optimize user performance time with discrete map segments that overlap by about 25%.

Olson, Judy M. (1975) "The Organisation of Color on Two-Variable Maps" Cartography and Computing: Applications p. 267-294.

There are many types of maps on which color may serve a useful function. Color may be used to enhance or clarify information, it may be used to increase the visual appeal of a map, and in some cases it may be an indispensable ingredient in the sytem of encoding complex information. An example of the use of color to encode complex information is its use on two-variable "cross-maps" such as those currently produced by the U.S. Bureau of the Census. This technique presents two quantitative variables on the same map, and the symbol system, a fairly complex one when considered in detail, is a set of color combinations. The construction of a color scheme for two-variable maps must be based on several logical consideratins, or restraints, such that the scheme forms a coherent system. It is the development of this set of color combinations and its logic relative to the map message that is discussed in this paper. Such a color system represents a specific employment of color and is presented as a sort of "case study." [ALSO IN COLOUR].

Peterson, Michael Paul (1981) Map, Image & Mind: A Pattern Quality Test of Some Graduated Symbol Maps, Dissertation - State University of New York at Buffalo, Sept. 1981.

Rogers, Steven P. (1984) "Human Engineering Analyses Used in the Development of a Computer-Generated Map Display for Army Aviators" in Proceedings of the 5th Annual Conference & Exposition, Vol. II - Technical Sessions, National Computer Graphics Assoc.

The Integrated Mission Planning System (IMPS) provides a revolutionary color map display that translates and rotates in real time with aircraft movement. Digital terrain elevation data is used to contruct shaded "relief map" images, perpective views, perform required computations, and interact with a terrain correlation system. Examples of human engineering analyses and experiments leading to functional requirements, display and control design criteria, and aviator-computer dialogue structure are described.

Traeger, Mary (1983) "A Color System for Computer-Generated Cartography" Auto Carto V, Proceedings of the 5th International Symposium on Computer Assisted Cartography, p. 687-691.

Color is being used more often as a technique to represent entities within a Cartographic representation. Color, in the context of a map, if understood and properly manipulated, enhances and clarifies the portrayal of that information.

This being the age of the computer and advancing technology, there arises new applications for fundamental theories. In this study basic color theory is applied in the developing of a color system for computer generated cartography. The color is derived systematically through a numerical process. By using this system, the colors, once established can be repeated and reproduced through a computer driven 35mm matrix camera. The perceptual difference between color are achieved by visually selecting a series of color palettes. With numerical coding the colors can then be matched and displayed in a map format for testing. This presentation demonstrates the application of basic color theory concepts using this approach.

White, Dennis (1980) "Interactive Color Mapping" Auto Carto IV, Proceedings of the International Symposium on Cartography & Computing, Applications in Health & Environment, Vol. 1, American Congress on Surveying & Mapping.

The information theory model of cartographic communication depicts the map maker as sender of information, the map reader as receiver and the map as the communication medium. The model helps to clarify the two different communication processes of encoding (preparing) the map and decoding (interpreting) the map, and distinguishes between the mental maps of the sender and receiver and the material map of the medium.

Interactive color mapping involves these various components of the communication process. In preparing the map, the nature of the geographical data induces a range of choices for color symbolism. Secondly, the capabilities of the map display equipment provide a set of available colors. And thirdly, the interpretation of the map by readers or viewers is affected by the physiological and perceptual characteristics of color.

Yamahira, Takuya, Yutaka Kassahara & Tateyuki Tsurutani (1985) "How Map Designers Can Represent Their Ideas in Thematic Maps: Effective User Interfaces for Thematic Map Design" in Proceedings Graphics Interface '85, Canadian Info. Processing Society, May 27-31, 1985.

Problem analysis in designing thematic maps and user interfaces which assist map designers in incorporating their ideas into maps are presented.

Problems in designing choropleth maps are analyzed from the map designers point of view. A graphical user interface, called "Histogram Interface" is implemented as a countermeasure for problems in designing choropleth maps. The user interface can assist the map designers in representing their ideas and achieving the desired resulting maps through the designing process. The user interface operations, which correspond to the map designer's ideas, are explained. The user interface effectiveness is confirmed by resulting map examples and the corresponding graphical patterns of the interface.

A concept is proposed concerning the importance in any computer graphics field, which the designers should consider in designing how to incorporate their ideas into pictures.

Menus

Allen, R. B. (1981) "Cognitive Factors in the Use of Menus and Trees" National Telecommunications Conference, New Orleans, LA, p: 1981a F2.5.1-2.5.5 Conference Records.

Users without prior computer experience employed menus and trees to search data base. The time for each response and errors made in reaching the target were examined. The results of the experiment and additional issues in cognitive human factors are discussed.

Apperley, M.D. and G.E.Field (1985) " A comparitive evaluation of menu-based interactive human-computer dialogue techniques". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

Menu selection is an often used type of human-computer dialogue. However, there is little data on the effectiveness, efficiency or merits of this technique . This paper describes an experiment designed to compare the utility of recently published intuitively derived techniques relating to the syntax of menu interaction with more conventional menu techniques. This experiment is a complex problem solving task which involves retrieving a number of related items from a data-base using a menu dialogue. Subjects will be presented with a task for which they must access, interpret and relate information from several different pages of a Viewdata-like database. Traversal paths and time taken to achieve the goal, are monitored, to provide data with which to assess the effectiveness of the menu syntax. It is anticipated that these results will be of significant interest to the designers of Viewdata systems, and to all people interested in human-computer interaction.

Billingsley, Patricia A. (1982) "Navigation Through Hierarchial Menu Structures: Does it Help to Have a Map?" Proceedings of the Human Factors Society -- 26th Annual Meeting.

The human/computer interface for many information retrieval systems is a hierarchical menu structure. Although this type of interface has several advantages for novice users, there is a great potential for confusion and disorientation when menu structures are large and complex. This experiment demonstrated that subjects given the opportunity to study a map of the menu organization for a prototype database showed an overall improvement in information retrieval performance across time. Subjects who studied a linear index of corrrect menu choice sequences showed a general decline in performance as the time between studying the index and new retrieval tasks increased. A control group was slower and made more unnecessary choices than either the map or index group. The results suggest that access to a pictorial representation of a menu structure facilitates the development of a workable, relatively long-lasting mental model of that structure.

Dray, S. M., W. G. Ogden & R. E. Vestewig (1981) "Measuring Performance with a Menu-Selection Human-Computer Interface" Proceedings of the Human Factors Society -- 25th Annual Meeting.

We compared speed and accuracy of operators using either multiple item line menus or menus calling sub-menus. Results suggest that naive users are faster when using menus which present all of the inforamtion on one screen (multiple-item line menus). Once trained, however, operators perform faster with menus calling sub-menus.

Foley, James D., V.L. Wallace & P. Chan (1984), "The Human Factors of Computer Graphics Interaction Techniques", IEEE Computer Graphics and Applications, Nov. 1984.

The promise of interactive graphics is to provide a user-computer communications medium that is at once benign, responsive, and graphic. We expect it to be benign and responsive in teh same sense a trusted servant is expected to be. We expect it to be graphic with the clarity and richness of communication that only graphic communication presents. When a person uses and interactive graphics system to do real work, he wants the system to virtually disappear from his consciousness so that only his work and its ramifications have a claim on his energy.

This promise is frequently not fulfilled. Designers of graphics systems - software and hardware - often lack the intuition, knowledge, and experience necessary to "engineer" the forms of dialogue between user and computer to best advantage. The fault lies partly in a lack of current literature, partly in a lack of educational opportunities, and partly in or lack of knowledge of methods and information structures by which such designers can be successful. Well-designed systems are usually the result of a diligent, essentially creative, enterprise.

We believe that one of the most important elements in the design of interactive user-computer interfaces in the selection of the devices and techniques by which the user performs elementary tasks. The purpose of our work is to provide a systematic structure to aid the designer in making this selection.

Kemp, S. et al. (1983) "Ergonomics Aspects of Menu-Based Dialogues for Man-Computer Interaction" in Karenna Coombes (ed.), Proceedings of Ergonomics Society's Conference.

Menu based dialogues provide a very convenient form of man-computer interaction. At any particular stage in the user's selection of computer functions or items, the menu presents the available choices. The selection of inappropriate items is excluded, thus reducing the need for error correcting routines on the part of computer or human operator. The user is guided through the sequence of activities which constitute his task. Overall, the menu structure serves to reduce the demands on his memory. This type of interaction is especially suited to naive and infrequent users;

there are some suggestions that it may prove slow and frustrating for experienced operators who have developed their understanding of the complete system.

Kiger, John I. (1984) "The Depth/Breadth Trade-Off in the Design of Menu-Driven User Interfaces" International Journal Man-Machine Studies, Vol. 20, p. 201-213.

An experiment is reported investigating the role of depth and breath of menus and tree structures in user interfaces for information-retrieval systems. The results suggest minimizing the depth of tree structures by providing menus of eight or nine selections each. This limit on menu breadth is consistent with known limits on human information processing capacity.

Perlman, G. (1985) "Making the right choices with menus". In Human-Computer Interaction - INTERACT '84 by Shackel, B (Ed.), North Holland, 1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

Menus provide an effective way to present a limited set of options to users. System designers have to decide how many options to present in what format, and how users will indicate their choices. Two experiments are reported that manipulate (1) menu size, (2) option ordering, (3) option selector type, and (4) selector/option compatibility. The results show (a) people use simple search strategies for ordinary menu sizes, (b) people are sensitive to menu length, (c) sorted menus are easier to search and (d) letter selectors can produce the best or worst performance depending on compatibility. Some guidelines for menu design and suggestions for further research are discussed.

Savage, Ricky E. & Habinek, James K. (1984) " A Multilevel Menu-Driven User Interface: Design and Evaluation Through Simulation" in Human Factors in Computer Systems, Thomas, J.C. & Schneider, J.C., Ablex, New Jersey.

The design and evaluation of a menu-driven user interface for a general purpose system is described. Analysis of errors made by participants in simulation studies of the interface led to the development of hypotheses concerning user choice behavior. For example, novice users had difficulty selecting menu options based on job titles rather than tasks and functions. Redesign of the interface to reflect these hypotheses resulted in significantly improved performance. The current version of the interface appears to accommodate both the novice user, through a extensive hierarchy of menus, and the experienced user, through a variety of shortcuts to system functions.

Shoup, Richard G (1983) Menu-Driven User Interfaces for Videographics" SMPTE Journal. Publication for the Society of Motion Picture and Television Engineers. No.92,Nov,1983, p1208-1210.

A menu is an array of choices of action or objects available to a user at any given time. At a videographics creation station, this array can be displayed graphically or with text only, on a video monitor or terminal screen. This article describes types of menus, and hardware and software tradeoffs in menu design for videographics creation systems. A typical implementation in software is described. Menus are discussed in terms of user interface design principles and criteria such as clarity, machine attitude, use of modes, hierarchies and branching, feedback, and safety checks.

Research

Bannon, Liam and Claire O'Malley (1985), "Problems in Evaluation of Human-Computer Interfaces: A Case Study". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conference organised by the Task Group on Human-Computer Interaction.

One of the most difficult aspects of interface design is evaluating new of changed features of an interface. In this paper we discuss methods of evaluation, their strengths and weaknesses, in the context of a program we developed to assist users in getting quick access to information contained in the UNIX manual. We outline the problems encountered both in the design and the evaluation of this user interface.

Beringer, Dennis B. (1979) "The Design and Evaluation of Complex Systems: Application to a Man-Machine Interface for Aerial Navigation" in Proceedings of the Human Factors Society- 23rd Annual Meeting.

Sytematic and economic design and evaluation strategies were applied to a computer-generated 4-D aerial navigation system. During the evaluation each of 24 experienced instrument pilots received training in a PLATO-based digital flight simulator using either a keyboard entry/static map, keyboard entry/dynamic map, or touch entry/dynamic map system. Tasks performed during the execution of an area navigation course included continuous flight control, navigation data updating, digital data entry, and amended course plotting. Digital data entry training time was comparable for all three systems but the touch-map proved superior for the plotting tasks, greatly reducing training and task execution times while virtually eliminating errors. Subsequent performance evaluation showed that the touch-map reduced flight path tracking error, increased processing rates on a digit-cancelling secondary task, and increased the accuracy of manual plotting operations. It was concluded that a touch entry system could significantly reduce cockpit workload across a wide range of operational environments.

Blake, Tyler (1984) "Beyond 'User Friendly': Using Human Factors to Evaluate Interactive Graphic Interfaces: in Proceedings of the 5th Annual Conference & Exposition, Vol. 1 - Tutorials, National Computer Graphics Assoc.

A half-day tutorial focusing on the evaluation off interactive graphic interfaces using analytical methods and measurement techniques derived from human factors engineering and applied psychology. Emphasis will be placed on pragmatic methods of modifying traditioanl techniques to deal with the constraints of the contemporary systems development process.

Application examples will include selecting alternative input devices, comparing decision-aiding systems and evaluating graphic display quality. The special problems of evaluating human behavior and performance will be addressed.

Card, Stuart K., Thomas P. Moran, Allen Newell "The Keystroke-Level Model for User Performance Time with Interactive Systems" Communications of the ACM, Vol. 23, No. 7, July 1980, p. 396-410.

There are several aspects of user-computer performance that system designers should systematically consider. This article proposes a simple model, the Keystroke-Level Model, for predicting one aspect of performance: the time it takes an expert user to perform a given task on a given computer system. The model is based on counting keystrokes and other low-level operations, including the user's mental preparations and the system's responses. Performance is coded in terms of these operations and operator times summed to give predictions. Heuristic rules are given for predicting where mental preparations occur. When tested against data on 10 different systems, the model's prediction error is 21 percent for individual tasks. An example is given to illustrate how the model can be used to produce parametric predictions and how sensitivity analysis can be used to redeem conclusions in the face of uncertain assumptions. Finally, the model is compared to several simpler versions. The potential role for the Keystroke-Level Model in system design is discussed. Key Words and Phrases: human-computer interface, human-computer interaction, user model, user performance, cognitive psychology, ergonomics, human factors, systems design.

Granda, Thomas M. "A Comparison Between a Standard Map & a Reduced Detail Map within a Simulated Tactical Operations System (SIMTOS)" U.S. Army Research Institue Techincal Paper 274, Essex Corp., Alexandria, VA, June '76.

The use of reduced maps in place of standard Army maps has often been recommended for the upper command (e.g., division) levels. Within the context of a simulated tactical operations system, several variables that were thought most likely to be affected by the use of reduced detail maps or echelon information needs were observed in an offensive planning phase and an offensive combat phase. Among the dependent variables included were number of data frames accessed, time to access data frames, and combat effectiveness scores.

The analyses of variance performed on the variables show significant main effects for the echelon factor for the amount and type of information accessed, and for one combat effectiveness score. No significant difference in performance during planning or combat was associated with the level of map detail factor. Therefore, the feasibility of using reduced detail maps in conjunction with a computerized graphic display capability should be investigated.

Moses, Franklin L., Richard E. (1979) "User Performance Under Several Automated Approaches to Changing Displayed Maps" U.S. Army Research Institute for the Behavioral & Social Sciences Technical Paper 366, Alexandria, VA, June 1979.

Performance in a route selection task was used to evaluate automated methods for changing from one displayed segment of a map to another. Participants were 24 Army officers, who chose successive 6.75 x 9 km map segments (1:50,000 scale) for solving 12 problems. Each problem requested the fastest road route between pairs of cities within a 60 x 81 km region. Participants solved problems by electronically marking road routes across map segments. Methods for changing map segments were a) continuous map scanning and b) discrete map segments using three different amounts of border overlap (0%, 25% and 50%). Results showed that different map change conditions did not significantly affect the quality of routes chosen. The least time for problem solutions occurred when map segments with 50% overlap were used, although 25% overlap produced similar data. Designers of map display systems for the military could optimize user performance time with discrete map segments that overlap by about 25%.

Shneiderman, Ben (1978) "Improving the Human Factors Aspect of Database Interactions" ACM Transactions on Database Systems, Vol. 3, No. 4, Dec. 1978, p. 417-439.

The widespread dissemination of computer and information systems to nontechnically trained individuals requires a new approach to the design and development of database interfaces. This paper provides the motivational background for controlled psychological experimentation in exploring the person/machine interface. Frameworks for the reductionist approach are given, research methods discussed, research issues presented, and a small experiment is offered as an example of what can be accomplished. This experiment is a comparison of natural and artificial language queery facilities. Although subjects posed approximately equal numbers of valid queries with either facility, natural language users made significantly more invalid queries which could not be answered form the database that was described. Key Words and Phrases: human factors, database systems , data models, query languages, natural language interfaces, psychology, experimentation.

Shneiderman, Ben (1982) *Human Factors Experiments in Designing Facilities in the 1980's*, IEEE Computer Society Press.

Providing useful tools for computer users with a wide range of experience, problems, skills, and expectations is a challenge to scientific competence, engineering ingenuity, and artistic elegance. System developers are increasingly aware that ad hoc design processes, based on intuition and limited experience, may have been adequate for early programming languages and applications but are insufficient interactive systems which will be used by millions of diverse people. Regular users quickly pass through the gadget fascination stage and become demanding users who expect the system to help them in performance of their work. Clearly, therefore, interactive computer-based consumer products for home, personal, or offfice applications require increasing levels of design effort.

Sidonek, Walter (1977) "Methodology for Evaluation of Image Enhancement Techniques" *Human Factors, 19*(3), 263-272.

A two-phased experimental design is proposed for evaluation of Synthetic Aperture Radar (SAR) image enhancement techniques. In SAR operation crew tasks are clearly differentiated into cognitive and psychomotor behaviors. Accordingly, Phase 1 static adaptive learning experiments are designed to assess cognitive (image interpretation) behavior, and Phase 2 real-time simulation experiments assess psychomotor behaviors associated with target designation and tracking. The two-phased paradigm can be effectively applied to any electro-optical image quality/enhancement design study. The two-phases are complementary and offer an improved and more cost effective methodology as contrasted to the use of classical ANOVA designs for the entire procedure.

Streveler, Dennis J. & Peter B. Harrison (1984) "Measuring the 'Goodness' of Screen Designs" Hawaii International Conference on System Sciences. Computer Net Subconference (7th, 1984: Honolulu, Hawaii) Padunch ewit, Ittipon.

Methods of measuring the "goodness" of the syntactical properties of a CRT screen design are presented. These methods include Boxing Analysis, Hot Spot Analysis and Loading Analysis. An example from clinical medicine, the reporting of laboratory results, is used to demonstrate these methods.

Thackray, Richard I., R. Mark Touchstone, (1982) "Performance of 40-to-50 Year Old Subjects on a Radar Monitoring TAsk: The Effects of Wearing Bifocal Galsses & Interpolated Rest Periods on Target Detection Time" Civil Aeromedical Research Institute, Oklahoma City, OK, April 1982.

The present study examined the effects of wearing bifocal glasses and interpolated rest periods on the performance of 40-to-50 year-old subjects on a radar monitoring task. The visual display was designed to resemble an air traffic control radar display containing computer-generated alphanumeric symbols. Forty men and women were divided into four equal-sized groups, with each group consisting of one of the four possible combinations of bifocal/no-bifocal and rest/no-rest conditions. All subjects were tested over a 2 hour session. Rest periods (a 5 minute break every 30 minute) significantly reduced the performance decrement of 40-to-50 year-old subjects, bringing performance to a level approximating that of 18-to-29 year old subjects without rest periods. The wearing of bifocal glasses did not contribute to visual strain or somatic discomfort.

Whitfield, D. & A. Jackson (1982) "The Air Traffic Controller's Picture as an Example of a Mental Model" in Analysis, Design and Evaluation of Man-Machine Systems by Johannsen, G. & J.E. Rijnsdorp, Proceedings of the IFAC Conference, Sept. 1982.

Air traffic controllers refer to the 'picture': their overall appreciation of the traffic situation for which they are responsible. In particular, great importance is attached to the controller's maintaining an appropriate picture when control and decision making responsiblities are shared between man and computer. We are making three initial approaches to elucidating the nature of the picture. 1) Interviews with controllers have defined some major characteristics. 2) Operational controllers have given 'verbal protocol' accounts of establishing the picture before taking over a sector position from a collegue. 3) Controllers working within a real-time simulation later observe a complete replay of radar display, flight plans, and speech communications for particular sessions, during which replay they record verbal protocols and provide futher explanation. Initial results are presented, and the potentialities, limitations, and future development of the techniques are discussed. Keywords: air traffic control, behavioural sciences, cognitive processes, cognitive systems, computer applications, ergonomics, human factors, man-machine systems, skills.

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Technical

Anderson, G. Leigh (1976) "Image Restoration Based on a Subjective Criterion" IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC - 6 No. 12, December, 1976

The problem of removing random noise from gray tone images without significantly sacrificing the subjective resolution is considered. Based on a subjective visibility function, which gives the relationship between the visibility of a unit noise and a measure of local spatial detail (spatial masking), two procedures are developed to adapt continuously the finite impulse response of a two-dimensional, noncausal, linear digital filter. At sharp transitions in the image intensity, the filter operator is strongly peaked to preserve the resolution, whereas in flat areas it is flat to effectively average out the random noise. The first procedure (s-filter) is computationally more efficient, but does not perform as well as the second method (sd-filter) which requires solution of a new optimization problem at every picture element. Results of several simulations are presented to demonstrate the feasibility of our approach. Extensions are pointed out to incorporate different adaption procedures and psychovisual criteria other than the type of spatial masking used here.

Boreham, Dominic, Ernest Edwards, (1982) "Extracting Shapes from Grey-Scale Images" International Journal of Man-Machine Studies, 16, 315.

The present work is concerned with grey-scale raster images having more than one bit per pixel, and is an extension, both practically and conceptually, of the earlier work. The transition to grey-scale images introduces a number of problems relating to the structure of images, or more precisely, the structure which the user perceives in the image. Our basic operation on an unstructured grey-scale image is EXTRACT. It corresponds to SAVE, but is more complex both in operation and function. Yhe purpose of the EXTRACT routine is to enable the computer to identify an unstructured shape which the user perceives on the raster screen and which he points to by placing a cursor within it. A shape cannot be identified by the computer merely in terms of a standard analysis of grey-tones appearing in the image on the screen. The separation of the shape from its background is a function of the user's perception, which we will see involves image structuring criteria, sometimes of considerable complexity. In most cases we are dealing not with the physical image on the screen, but with the user's percept, which is an interpretation of the screen image.

Coquillart, Sabine & Michel Gangner (1984) "Shaded Display of Digital Maps." IEEE Computer Graphics and Applications Vol. 4, No. 7, 1984.

The computer graphics display of shaded images of terrain can take advantage of the geometric properties of the data. Altitudes given on regular rectangular grids are readily available from digital maps. Several authors have addressed the task of displaying such data. Line-drawing methods are well known, and there have been two new contributions in the recent literature.

Two problems arise in displaying a perspective view of a terrain. The first is to choose an interpolation surface; the second is to eliminate hidden surfaces.

Foley, J. D. & A. Van Darn (1982) Fundamentals of Interactive Computer Graphics. The Systems Programming Series, Addison-Wesley Publishing Company.

Grundey, Ing. K., U. Schweitzer & R. Neuser (1985) "A User-Friendly Computer-Aided Construction of Boundaries" in Proceedings Graphics Interface '85. Canadian Info. Processing Society. May 27-31, 1985.

To calculate a Digital Terrain Model (DTM) of any set M of measuring points

$$M = \{ (x(i), \ y(i), \ z(i)) \mid i = 1, ..., n \}$$

it is often neccessary to combine some subsets of M. Such subsets may be special point sets e.g. boundaries, slopes, break points, etc. Such point sets are important for calculating the altitudes of DTM grid points, because they influence the selection of the correct neighbourhood of the grid point in question. We wish to present a fast and user-friendly algorithm to calculate such point sets.

Herot, Christopher F. (1982) "Spatial Management of Data" in Larson, James A. Tutorial: End User Facilities in the 1980's IEEE Computer Society Press, 1982.

Spatial data management is a technique for organizing and retrieving information by positioning it in a graphical data space (GDS). This graphical data space is viewed through a color raster-scan display which enables users to traverse the GDS surface or zoom into the image to obtain greater detail. In contrast to conventional database management systems, in which users access data by asking questions in a formal query language, a spatial data management system (SDMS) presents the information graphically in a form that seems to encourage browsing and to require less prior knowledge of the contents and organization of the database.

This paper presents an overview of the SDMS concept and describes its implementation in a prototype system for retrieving information from both a symbolic database management system and an optical videodisk. Key Words and Phrases: computer graphics, man-machine interaction, database query languages, graphics languages.

Hudson, Scott E. & Roger King "Efficient Recovery & Reversal in Graphical User Interfaces Genrated by the Higgens System" in Proceedings Graphics Interface '85, Canadian Info. Processing Society, May 27-31, 1985.

The Higgens user interface generation system being developed at the

University of Colorado allows an interface designer to rapidly construct graphical user interfaces based on a primarily non-procedural interface specification. This paper discusses how user recovery and reversal, or Undo, is performed within a Higgens generated interface. A special data model is developed which has unique properties which combine to provide an efficient environment for implementing an undo mechanism. New algorithms based on recent work in incremental attribute evaluation are used to efficiently implement both the generated interfaces as a whole, and the undo mechanism in particular. In addition, a formal model of undo is used in an attempt to evaluate the power of the mechanism in order to compare it with other undo implementations. Key Words: Recovery, Reverse Execution, Undo, Graphics Based Interface, User Interface Management.

Kovaly, John J. (1976) Synthetic Aperture Radar , Artech House, Inc.

Mitchell, R.H. and Stanley Marder (1981)," Synthetic aperture radar (SAR) image quality considerations" Proceedings SPIE, International Society of Optical Engineers Vol.310 Image Quality (1981), p.58-68.

Characteristics of radar scattering, the SAR imaging process, and display devices are considered with respect to their effects on the quality of the resulting image. A set of SAR image quality measures are specified which relate to application information requirements and associated measurement techniques are presented.

Plott, Herman H. Jr., J. David Irwin & Lewis J. Pinson (1975) "A Real-Time Stereoscopic Small-Computer Graphics Display System." IEEE Transactions on Systems, Man & Cybernetics Vol. SMC - 5 No. 5, Sept. 1975.

A brief review of the principles of steroscopy is given followed by a discussion of candidate methods for providing stereoscopic viewing of display data. An analog computer implementation of a stereoscopic graphics display system is described. The analog implementation provides real-time display capability but has no data storage capability. Implementation with a small digital computer provides data storage but is significantly slower for displaying dynamic changes in the data. Other points of comparison between the two systems are given with the conclusion that a hybrid system would combine good features of both. Experimental evaluation relative to eye fatigue is given for three specific viewing techniques. Example stereograms are given for both the digital and analog systems. Of particular interest was application of the display system for viewing biomedical data, as illustrated by an example display of a vectorcardiogram.

Tamura, Hideyuki, Shunji Mori and Takashi Yamawaki (1978) Textural Features Corresponding to Visual Perception", IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC 8, No. 6, June 1978.

Textural features corresponding to human visual perception are very useful for optimum feature selection and texture analyzer design. We approximated in computational form six basic textural features, namely, coarseness, contrast, directionality, line-likeness, regularity, and roughness. In comparison with psychological measurements for human subjects, the computational measure gave good correspondences in rank correlation of 16 typical texture patterns. Similarity measurements using these features were attempted. The discrepancies between human vision and computerized techniques that we encountered in this study indicate fundamental problems in digital analysis of textures. Some of them could be overcome by analyzing their causes and using more sophisticated techniques.

Winter, James (1984) "Automated Comptuer Tomography Image Analysis Using Contour Map Topology" IEEE Transactions on Medical Imaging Vol. MI-3, No. 4, Dec. 1984.

The topology of a discrete contour map exactly representing a digital image provides a simple structural oraganization for image recognition. Success was achieved at algorithmic identification of normal anatomy and tumor in X-ray computed tomography of the brain. Image analysis using contour map topology identified only those image brightness thresholds having significance for object segmentaion. The computer selected contour lines correspond exactly to the sketch that a physician would draw to depict the image.

Winter, James (1984) "Discrete Contour Map Representaion of Image Matrices" IEEE Vol. MI-3, No. 4, Dec. 1984.

An arbitrary integer picture matrix can be exactly and uniquely encoded as a tree structured discrete contour map. This new discrete contour map model requires only closed contour lines composed of chain coded vertical or horizontal unit length directed line segments. An exmaple is given of an X-ray computed tomogram showing a brain tumor and hydrocephalus which is analyzed by this contour map image processing.

Visual

Engel, F. L. (1977) "Visual Conspicuity, Visual Search and Fixation Tendencies of the Eye" Vision Research Vol. 17, p. 95 - 108.

The cumulative probability of target discovery during search has been related experimentally to the relevant "conspicuity area", the visual field in which the target can be discovered after a single eye fixation. During search "non-targets' were found to be fixated spontaneously in proportion to their conspicuity area.

Further small spontaneous eye fluctuations are described that occurred, during determination of the conspicuity areas, in the direction of the target discovered. Their occurrence and delay depended on the target eccentricity and the six of the conspicuity area.

The results emphasize the relevance of the conspicuity area to research on visual selection. Key Words: visual conspicuity; visual search; spontaneous eye movements; selective attention.

Frome, Francine S., Steven L. Buck and Robert M. Boynton (1981) " Visibility of borders: separate and combined effects of colour differences, luminance contrast, and luminance level" Journal of the Optical Society of America, Vol.71, No.2,1981.

The strength of the border between two regions was assessed be measuring the tendency of the border to disappear during a 5-min fixation period. We measured the total time the border was judged visible when subjects viewed two hemifields with different chromaticities (six wavelength pairs), five luminance contrasts of with differences in both, at five levels of luminance . For a homochratic field, border visibility increased linearly with the logarithm of the luminance contrast, regardless of the particular wavelength of the field. For fields with only chromatic differences, border visibility increased linearly with the logarithm of the tritanopic-purity difference (the relative activity of only the long- and middle- wavelength-sensitive cones). For all borders, visibility increased with an increase in luminance level. Thus borders formed by the combination of chromatic differences and luminance contrasts are more visible than borders that have the same chromatic difference or the same luminance contrast alone. For any chromatic difference, calculation of a luminance contrast that would yield the same border visibility were made. These equivalent luminance- contrast functions for border visibility provide a metric for chromatic differences across a range of luminances that allows chromatic and luminance-contrast sensitivities to be compared in a nonarbitrary way. Relative to chromatic differences, luminance contrast is less effective in maintaining border visibility at lower luminance levels. When the borders combine both chromatic differences and luminance contrasts, a root-mean-square model can be used to account for the data. This is consistent with the idea that chromatic and luminance systems make independent contributions to the visibility of borders.

Gibbs, S. Julian, Ronald R. Price, A. Everette James Jr. (1981) "Image Perception" in the Physical Basis of Medical Imaging, Cowlain, Craig M., et al. (eds), Appleton-Century-Crofts, Prentice Hall, 1981, Chapter 21, p. 295 - 302.

The final steps in a radiologic examination, the importance of which is overlooked in most texts, are perception of diagnostic information from the radiographic images and its integration with other information to arrive at a decision concerning patient management. For the purposes of this discussion, each image is assumed to be technically perfect or as nearly so as possible.

The actions of interpretation of a display of an image are:

1. Detection of those features of interest from the entire image
2. Interaction with the display system to improve the display of those features
3. Description of the significant features of the image
4. Integration with information obtained from other sources

5. Conclusion of the clinical relevance of the integrated information
6. Documentation of the conclusion in such a way as to influence future patient management (or to convince other clinicians)

Actions 1 and 2 involve perception of the image display. Actions 3 through 6 develop a decision, based upon that perception.

Gould, John D., (1968) "Visual Factors in the Design of Computer-Controlled CRT Displays" Human Factors, 10(4), 359 - 376.

This paper is concerned with the important visual variables that determine image quality on computer-controlled CRT displays. A strategy is developed that leads to general conclusions about each variable even though most of these variables ineract. For each variable considered, the recommended range of values is determined on the basis of experimental evidence and is compared with the values presently used on displays. Where discrepancies between these two exist, alternative solutions are mentioned. Conclusions are 1) presently used values of display luminance, chromaticity (color), and resolution are adequate; 2) several displays flicker; 3) characters are large enough but may be marginal in terms of number of elements; 4) luminance contrast is not adequate.

Grether, Walter F. and Charles A. Baker, (1972) "Visual Presentation of Information" in Van Cott, H.P. and R.G.Kincaide "Human Engineering Guide to Equipment Design, 1972.

Haber, Ralph Norman, Leland Wilkinson (1982) "Perceptual Components of Computer Displays" IEEE Computer Graphics and Application, May 1982, Vol.2, No. 3, p. 23 -35.

Computers have architectures and operating systems that determine the sequence and structure of their information processing. Human beings have their own architectures and operating systems that determine how they process information. Advances in cognitive psychology over the past several decades have revealed the varieties of architecture and operating systems underlying the information processing tasks humans normally perform. We now know a number of principles that specify the optimal organization of information for various types of human information processing.

The purpose of this article is to describe some of these organizational principles, especially those that affect communication between a computer and a user. Since this communication is frequently visual, most of what follows concerns principles of cognition that apply to graphic information. Some of these principles govern all forms of cognitive activity, such as perceiving, retaining, retrieving, imagining, creating, deciding, or acting. We will discuss these general principles first.

McCormick, John, Gerald Murch, Lyle Leavitt, (1984) "An Experimental Color Monitor for Vision Research" SPIE Proceedings, Vol. 457 Advances in Display Technology IV, The International Society for Optical Engineering, p. 26 - 30.

Visual science refers collectively to the research of the vision process from anatomical, neurological, physiological, psychophysical, opthalmological, and psychological points of view. Each of these disciplines in turn is concerned with some aspect of the multifaceted visual funtion. The work extends from studies of humans to a wide variety of other species with the ultimate goal of understanding this most critical link between living things and the environment.

Mills, Michael I. (1985) "Image Synthesis: Optical Identity or Pictorial Communication?" in Proceedings Graphics Interface '85, Canadian Info. Processing Society, May 27-31, 1985.

This paper reviews some ideas from E. H. Gombrich (an art historian) and Julian Hochberg (a perception psychologist) on artists' attempts to simulate reality in painting. These ideas suggest that workers in image synthesis enlarge the scope of their mission. Rather than trying to get computers to make images which are indistinguishable from direct perception, they should pay more attention to the use of computer graphics for "pictorial communication"--where departures from objective realism can sometimes lead to more effective displays and where the mental process of image interpretation should itself be a legitimate focus of research and experimentation.

Montalvo, Fanya S. (1979) "Special Session on Vision - Human Vision & Computer Graphics" ACM - Siggraph, Vol. 13, No. 2, Aug. '79, p. 121-125.

Is one picture really worth a thousand words? Why do cleverly designed graphic displays make visual information stand out more clearly with strikingly greater impact than numbers buried in pages of computer printout?

Graphic output devices shift the burden of integrating information generated by computer onto the human vision system: the sensory channel with the highest capacity for distributed parallel processing. The system consists of hundreds of successive two-dimensional arrays of millions of interconnected parallel computers. Perception seems instantaneous because we are not conscious of the massive amounts of computation that occur. What we consciously "see at a glance" is already a highly structured, sythesized, and summarized version of the actual light intensity mosaic that enters the retina.

We will demonstrate some results of the visual structuring that occurs in the human visual syste, show why some features stand out instantaneously and others do not, and explain why knowledge of the human input device is crucial to the design of effective computer output devices and displays.

Overington, Ian (1981)" Image quality and observer performance", Proceedings, SPIE, International Society of Optical Engineers, Vol.310 (1981), p.2-34.

The majority of images produced by optical and electro-optical equipment are destined to be viewed eventually by human observers. The human sense of sight itself exhibits a variety of imperfections of imagery (due to the dioptrics), internal noise (due to discrete image sabpling at the retina) and a variety of image transformations in the neural networks preceding the perceptual levels of the cortex. In addition all these characteristics are progressive fluctuations of retinal image position, whilst perceptual processes themselves are subject to both statistical fluctuations and influence from other factors. There are therefore many facets of imagery which interact with the human sense of sight, the importance of the individual interactions being largely dependent on the application to which the presented images are put.

An approximate representation of preperceptual image formation and tranformation by human vision will be presented. A unified approach to the modelling of visual performance will then be summarized which takes account of the various display/observer interface factors and attempts to allow for variability in perceptual processes. Finally it will be shown how apparently widely disparate approaches to visual performance modelling may be reconciled in terms of this unified approach.

Poggio, Thomas (1984) Vision by Man and Machine, Scientific American, Vol. 250(4), p. 106 - 116.

The development of computers of increasing power and sophistication often stimulates comparisons between them and the human brain, and these comparisons are becoming more earnest as computers are applied more and more to tasks formerly associated with essentially human activities and capabilities. Indeed, it is widely expected that a coming generation of computers and robots will have sensory, motor and even "intellectual" skills closely resembling our own. How might such machines be designed? Can our rapidly growing knowledge of the human brain be a guide? And at the same time can our advances in "artificial intelligence" help us to understand the brain?

Snyder, Harry "Vision and the VDU" ***NO REFERENCE (from ILL in error)***

This paper describes the fundamental properties of the visual display unit, its relationship to our visual system, the appropriate design considerations of the visual display unit, and references to data which permit us to perform an optimal design of the VDU. It is suggested that a large body of data exists on appropriate VDU design and the relationships between design parameters and human visual performance. If design criteria are taken carefully from this body of data, there is little or no evidence that significant visual problems result from prolonged usage of VDUs. Rather, it is further suggested that visual problems and worker complaint are often traceable directly to inappropriate VDU design and poor quality displays, thereby placing an undue load upon the visual system and the operator.

Tamura, Hideyuki, Shunji Mori and Takashi Yamawaki (1978) Textural Features Corresponding to Visual Perception", IEEE Transactions on Systems, Man and Cybernetics, Vol. SMC 8, No. 6, June 1978.

Textural features corresponding to human visual perception are very useful for optimum feature selection and texture analyzer design. We approximated in computational form six basic textural features, namely, coarseness, contrast, directionality, line-likeness, regularity, and roughness. In comparison with psychological measurements for human subjects, the computational measure gave good correspondences in rank correlation of 16 typical texture patterns. Similarity measurements using these features were attempted. The discrepancies between human vision and computerized techniques that we encountered in this study indicate fundamental problems in digital analysis of textures. Some of them could be overcome by analyzing their causes and using more sophisticated techniques.

Tamura. H. and N Takematsu (1985) " Legibility of the VDT required for high performance task". In Human-Computer Interaction-INTERACT '84 by Shackel, B (Ed.), North Holland,1985. Proceedings of the IFIP Conf[illegible]ce organised by the Task Group on Human-Computer Interaction.

This paper proposes an experimental method to evaluate legibility of the display and efficacy of the pointing device, to be applied to compare human performance both at VDT and paper-pencil systems. The result confirmed the performance is still considerably low compared to the paper-pencil system. The difference is larger for the task of the higher work load. The measure of performance defined in this paper may be used as the objective of improving devices.

Wheale,J.L. " The Visual Cues in an Approach to Landing" in Proceedings of Ergonomics Society's Conference, Karenna Coombes (Ed) 1983, p123.

Wicken, Christopher D. (1984) "Attention & Perception" Engineering Psychology and Human Performance, Merill Publishing Co., Chapt. 7.

The limitations of human attention, like those of working memory, constitute one of the most formidable bottlenecks in human information processing. We can all easily relate instances when we failed to notice or attend to the words of a speaker because we were distracted or our attention was directed elsewhere or occasions on which we had so many tasks to perform that some were neglected. These intuitive examples of failures of attention may be desribed more formally in terms of three categories: 1. The limits of selective attention. 2. The limits of focused attention. 3. The limits of divided attention.

Wicken, Christopher D. (1984) , "Non Verbal Perception" Engineering Psychology and Human Performance, Merrill Publishing Co., Chapt. 5, p. 163 - 183.

This chapter on nonverbal perception will focus on perception of stimuli that do not generally share one or more of these three properties. One concern will be the perception of objects or texture. Here the physical stimulus does not bear an arbitrary symbolic relation to the subject's concept of that stimulus, but bears a direct analog relation to it. The term "analog" implies that some physical equivalence exists between the stimulus and its mental representation. The equivalence may be achieved by continuous transformations of rotation, magnification, distortion, or translation. Thus a pilot's mental representation of an aircraft in space should have a direct analog correspondence with the true orientation of the actual aircraft. As a second contrast, unlike verbal stimuli, the information to be dealt with in in the present chapter is often perceived first as a set of lines and angles joined together, but is perceived intially as a whole box into its constituent elements.

Winston, Patrick Henry (ed.) (1975) The Psychology of Computer Vision, McGraw-Hill, Inc., NY.

APPENDIX A: INSTRUCTIONS FOR ICE CLASSIFICATION EXPERIMENT

A.1 Instructions

In this experiment you will be shown a series of SAR images of various ice types at varying degrees of resolution. Your task when you see each image will be to identify the ice type. There are five sets of images, one for each resolution. In each set there are 25 different images to respond to. To respond, you will be using the return key, the two keys labelled yes and no and the keys numbered 1, 2 and 3 on the right hand side of the keyboard.

ICE TYPES

Five different ice types are represented on the screen.

RESOLUTIONS 12, 24, 48, 96 and 192 meters per pixel.

THE TASK:

Your task is set up as follows:

1. START

When you are ready to start, you are instructed on the screen to press the RETURN key.

Press RETURN.

2. DESCRIPTION:

On doing so, a 3-line description of the image to follow will appear. It will give:

a) the region where the image was taken;

b) the season; and

c) the resolution in meters per pixel.

When you are ready, you are asked to press RETURN again.

Press RETURN.

3. QUESTION:

A question will then appear on the screen asking whether or not the image

shows a particular ice type. When you are ready, keeping the question in

your mind, press RETURN again to bring up the image.
Press RETURN.

4. IMAGE:

The area to interpret is marked out by the yellow box. If there seems to be more than one ice type within the box, concentrate on the feature appearing closest to the centre. Your task is to decide whether or not the ice type named in the text you just saw described the image outlined by the box. If it does, you should press the green YES key. If not, press the red NO key. We will be recording your response time so it is necessary that you concentrate on responding AS QUICKLY AND ACCURATELY AS POSSIBLE after the image appears. We want to find out how long it takes for the necessary information to be extracted from the image to make a judgement.
Press YES or NO.

5. LEVEL OF CONFIDENCE:

In making your decisions, you may or may not feel sure of them. If you are certain you have made the right decision, press 1. If you are not confident that your judgement is correct, press 3. If you feel some degree of confidence but are not certain, press 2.
Press 1, 2 or 3.

6. ANSWER

The question you were asked will appear together with the correct answer. When you are ready for the next task, press RETURN to bring up the text describing the next image.
Press return.

A.2 Further Comments

S2 Not enough context: experience of the area and its ice flows during that season contribute to the interpretation of the images.

S3 Am learning the E's categories as I progress.
The open water/new ice/young ice distinction is easier at 48 m/p res.
There is a subjective order effect going from 192 m/p directly to 12m/p res.
24 is a good resolution.

S4 Dislike definition of rubbled/ridged.
Not enough context to make judgements.
First three categories too close in definition.

S5 Rubbled/ridged category overlaps with others, especially with first-year ice. Also has problems of definition; doesn't make sense; too vague and descriptive, as opposed to the age or thickness criterion. It is nonsense to exclude rafting. Also rotten ice should not be included. In the field, the age of the ice is first classified and coded. Secondly, the ice is described (in terms of, for example, rubbled/ridged) and coded for its features.

S6 Is the grey-scale consistent throughout the images?
Were E's judgements made on the given or on higher resolution images?
Often forgot the question. Why not show it with the image?
Need more context information, e.g., nearshore/offshore.
Rubbled/ridged category is a problem; there are ridges in lots of different ice types.

S7 Need to know when in the fall. Before or after September 30th alters classification.
Need to know where in the sea. Inshore, offshore, in transitional zone, etc. all affect judgements.
Forget question.
Need to see larger part of the image's surroundings to interpret the ice.
Old ice is the hardest category on rigs.

Used location as a major clue in many cases. Same image in different location can be a different ice type.
E not consistent as to what they're calling old ice.

S8 Would prefer to categorize the ice as usual, instead of giving yes/no answers.
Basing judgements on what E said last time, contrary to own classification system.
Many of the images are aggregates of ice types.
Forget question - can it be displayed on the screen with the image?
Confidence level criteria changed throughout.
Need an arrow to point directly to the ice-type in question.
Need to know exactly when in the fall. Transition date 30th September determines whether young or first-year ice.

TABLE 6 : Disagreements and Mistakes

Key	S	Subject number
	D(data)	Disagreements (from the data)
	D(exp)	Disagreements (expressed)
	M1	Mistake in pressing yes/no keys
	M2	Mistake in pressing confidence-level keys
	SE	System error when 1, 2 or 3 pressed too fast

S	D(data)	D(exp)	M1	M2	SE
2	30	19	3	1	0
3	37	12	0	4	3
4	32	25	8	2	0
5	37	23	3	3	2
6	29	9	5	1	0
7	35	23	1	1	1
8	45	35	3	2	0

TABLE 7 : Ice interpretation

Information contributing to ice interpretation:

Water depth,
past climate,
wind conditions,
exact date of image, before or after 30th September determines ice class,
specific area of sea, offshore/ inshore, transitional zone,
currents,
features in surrounding image,
(salt content,
thickness of ice),
experience of area in previous seasons,
experience of particular flows in the past.

Some terms used to describe ice features:

Leads, ridges, rounded/ sharp edges, frost flowers, hummocks, pans, finger-rafting, sugar, spikules, horseshoe ridge, aggregate, rafted, ridged, brash ice, cracks, rough, rubbled.

Image Display System

User's Manual

The IDS User Manual

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IMAGE DISPLAY SYSTEM (IDS)

1.0 INTRODUCTION

IDS is an *Image Display System* designed for easy manipulation of RIDS and SAR images. It assists users in matching RIDS and SAR images, extracting regions of SAR images, and in basic SAR and RIDS image manipulation. Many useful features have been included, such as rotating images, and the ability to view images in either colour of black and white. A user-friendly work environment allows beginners to quickly learn how to use the system.

2.0 STARTING IDS

To run IDS, do the following:

```
ids [-b][-i file][-L line_len][-r angle][-X val][-Y val]
```

Anything within brackets (between '[' and ']') are optional, but using most of the options will save you time once you get into IDS. A brief explanation of each of the parameters follow below.

-b This option is used to indicate that the RIDS image is to be displayed using the B-scan format. Of course, if you do not want to see any RIDS images, you can ignore this.

-i This specifies the file from which the SAR image is to be loaded. This file name should be the complete path name if the image is not located in the current directory. Unfortunately, if you intend to display two SAR images, the second file name can be only be specified from within IDS.

-L This is used to set the length of a line of SAR imagery. The default is 4096, since (at the time of writing) this is the typical line length of SAR images. When loading in RIDS images that have been saved (or converted using 'rids') you should specify a line length of 512.

-r Is used to rotate the RIDS image by 'angle' degrees. You can alter this angle from within IDS as well.

-X Can be used to set the X offset into the SAR image. By excluding this, the portion of the SAR image displayed will begin at X equal to 0. This can also be set from within IDS.

-Y Can be used to set the Y offset into the SAR image. This also defaults to 0.

3.0 FROM WITHIN IDS

Now that you have finally gotten into IDS, you must know some of the basic keyboard operations in order to use all the functions visible on the screen.

First off, there is moving the cursor. This is simply done by pressing the arrow keys found on the keyboard. When moving longer distances, just press the appropriate arrow key and hold it down. However, be sure to release the key before you get to your desired destination. This is because of the keyboards tendency to remember keys (called *type-ahead*) and will cause the cursor to move merrily past the spot you want it to go to. The best way to prevent it from happening is to not hold the key down to long. If you should happen to do so, just wait for the cursor to stop.

If any image on the screen is being updated, the cursor will not move until the image update is finished. However, all keys are still being remembered, so be VERY careful. The only way to get a real feel for this, is to get into IDS and play with the cursor for a bit.

If you find the just moving to fast, press one of the number keys (1 through 0). The lower the number, the slower the cursor will go (except 0, which is considered to be 10). The default is five.

4.0 THE IDS SCREEN

IDS has seven sections in its screen layout. They can be found on diagram 1, and the following list explains what the purpose of each section is.

4.1 RIDS DATA AREA

This portion of the screen will usually display a RIDS image read off a tape drive. However, it can be made to display SAR imagery by toggling the button labeled "RIDS MODE" or "SAR MODE". If the button says "RIDS MODE", then selecting it will put this image area into use for RIDS imagery. When the cursor is moved into this area, the status line (not the RIDS or SAR status line) will display range of the cursor from the origin, the bearing (including the rotation factor), and the value of the data underneath the cursor using either a 1x1, 3x3, or 5x5 filter for averaging. The filter can be chosen by selecting the appropriate button.

NOTE: A bug that still existed at the time this manual was created is the inconsistency of the range, bearing, and pixel value when B-scan format is chosen. For this reason, you are recommended to ignore these values whenever in B-scan mode.

4.2 SAR DATA AREA

This area of the screen will always display some kind of SAR imagery. If you did not specify any image to display, it should be blank.

4.3 RIDS STATUS LINE

This area will usually display pertinent information to the "RIDS DATA AREA". In particular, the angle at which the RIDS image is rotated, the number of the image from the beginning of the tape, and the header of the RIDS image (usually containing date of creation and the sight at which it was created) are all displayed in this little window.

4.4 SAR STATUS LINE

This area is for information pertinent to the "SAR DATA AREA".

4.5 RIDS OPTIONS

This area contains all the buttons for selecting any options for the "RIDS DATA AREA". The appropriate buttons for the current mode will exist, and will change as you change the environment.

4.6 SAR OPTIONS

This is the same as the "RIDS OPTIONS" area, except it is for the "SAR DATA AREA" instead of the RIDS area.

4.7 STATUS LINE

This area is used to give you miscellaneous information about the cursor, or is used for user input. If you must answer any prompts, your input and the prompt will appear here.

5.0 IDS FUNCTIONS

All the functions that IDS is capable of is visible on the screen. By moving the cursor over the button containing the desired function and then pressing the space bar, the function is then executed. These functions are split up into two different sections. Those related to the RIDS data area are place under the RIDS data area, and those for the SAR data are place under the SAR data window. NOTE: For most of the SAR functions, you can select other options before the current one is completed. That is, if you rotated an image, the entire image will begin to be displayed again (except it will be rotated). Before the image redraw is done, you may select other options (ie mirror).

5.1 RIDS FUNCTIONS

B-SCAN	RIDS is normally displayed in a radial format. While this is good for most purposes, you might find it beneficial to view the image in B-Scan format. In this format, all imagery close to the origin (ship) is displayed along one edge (the top), and as you descend the image, you are moving away from the origin. Because of the nature of marine radar, the image closer to the ship tends to contain more detail. Note that this button will toggle functions between B-SCAN and RADIAL.
COLOUR	With this, you can choose between a colour display and a grey scale display. Note that the entire screen will change between colour and grey scale. Also note that the button toggles between "COLOUR" and "GREY".
PAUSE	Normally, IDS will continually be reading in RIDS images off of the tape drive, and immediately display them. This makes close examination of a given image very difficult. By selecting pause, the display will freeze, leaving the current image on the screen until the "RESUME" button is pressed. Note that this button toggles between PAUSE and RESUME.

QUIT	With this, you may exit the program. You will first be asked if you are sure about the exit. Only an answer of "Y" (in upper or lower case) will cause the program to exit. All others are considered to mean "NO".
REWIND	This will just rewind the tape from which the RIDS data is read. This is handy for backing up to old images since you can not "SKIP" backward. To view an old image, rewind the tape and then skip forward (via the SKIP button) to the image desired.
ROTATE	This permits rotation of the marine radar imagery by any number of degrees from its current position. This function allows users to match SAR and RIDS images that are not in the same orientation (as is usually the case).
SAVE	This allows you to save the current RIDS image being displayed. It is saved in SAR format, with a 512 by 512 screen resolution. You will be asked for a filename to save the image under. A complete UNIX pathname can be given. NOTE: Since the image is save in SAR format, you can display the image using the SAR portion of display, or you can use the "sload" or "image" utilities found elsewhere in the system.
SET CONTRAST	Sometimes the image displayed is not bright enough. When this button is selected, you are prompted with a contrast multiplier and shift values. The multiplier stretches the brightness out. That is, bright spots are made brighter, and dark spots darker. The larger the value you enter, the brighter the bright values become. The shift value, however, just causes the entire image to become brighter (with large positive values). Dark spots are just as dark relative to the bright spots, but the entire image is brighter compared to before.
SKIP	This allows you to skip past a specified number of RIDS images. This is extremely handy, since hundreds of marine radar images may be contained on one tape.

1 BY 1 3 BY 3 5 BY 5	This function allows you to specify the size of the rectangle to average in order to get the pixel value under the cursor. A 1 by 1 filter would give the pixel value immediately under the cursor. A 3 by 3 will average nine pixels (the 8 pixels surrounding the cursor, and the one under the cursor), while a 5 by 5 will average 25 pixels. NOTE: This button does not display the current chosen filter size. Instead, it shows the next filter size you could chose. This button will rotate filter sizes between 1 by 1, 3 by 3, and 5 by 5.

5.2 SAR FUNCTIONS

FLIP	This allows the image to be "flipped" upside-down and back again. When the image is flipped, the status bar underneath the data window will show that it is activated by the letter F in the first position of the flags list (ie the first character following F: in the status area). If the option is deactivated, a '-' character will be in its place. NOTE: If the ROTATE function has been used twice, the 'F' flag will be set (ie two rotates is the same as a flip).
HISTOGRAM	This function was not implemented at the time this manual was written.
HORIZONTAL MOVE	Due to the size of most SAR images, not all of the image is displayed on the screen at one time (except, when the ZOOM is set up). This function allows you to enter the horizontal coordinates to display from. This coordinate will be at the top left corner of the SAR data window and is measured in pixels. You will be prompted for the coordinate to move to.
LOAD	This will load another SAR image in place of the one currently being displayed. You will be asked for the filename (please ensure that you enter a valid UNIX pathname). Entering nothing (just return) will exit without changing the current image in any way. Then you will be asked for the length of a scan line (just enter the width of the image) and if the image is four bit data or not. Most SAR images are 8 bit data, unless it is downlinked, in which it is probably 4 bit data.

MIRROR	While FLIP lets you turn the image upside-down, MIRROR lets you look at mirror images of the image. When MIRROR is activated, the second character in the SAR status window will be M, otherwise it will be '-' (this is the second character or the character following the flip flag). NOTE: Again, rotating the image may cause this flag to be set.
ROTATE	This allows you to rotate the SAR image in increments of 90 degrees (0, 90, 180, 270, etc). The third character in the flags field of the SAR status window will show 'R' if the image is rotated. NOTE: Rotating more than once may cause either the FLIP or MIRROR flags to toggle.
SAVE	This allows you to save the SAR image currently being displayed. This does NOT save the entire image; just the portion within the SAR data window WITHOUT loss of data. The size of the image should be noted from the SAR status window (the numbers after W: and H: [width and height]). This is extremely useful for extracting regions of SAR images with great ease (See the ZOOM function).
SET CONTRAST	This is the same as the SET CONTRAST function for the RIDS data (see section 5.1).
SIMULATE	This function was not implemented at the time this manual was written.
VERTICAL MOVE	This is the same as HORIZONTAL MOVE except it is used for vertical movements instead of horizontal.
ZOOM	Sometimes you will want to find a specific spot on an image. Doing this without a hard copy is usually difficult since the entire image can not be displayed. To get around this, ZOOM allows you to zoom in or out of an image. This means that the entire image may be displayed if you want. However, when showing images with a width and/or height greater than 400, lines of the image will be eliminated in such a way as to preserve the image as much as possible (NOTE: Decimation is used since it is faster than averaging). If you zoom in with a width and/or height smaller than 400, some pixels will be larger than normal since the data resolution can not be improved upon. When saving a region, you must use zoom to ensure that the entire region is within the SAR data window. If this is not done, only the portion of the region within the data window will be saved. NOTE: The W and H values (width and height) in the SAR status window will reflect the zoom box size.

6.0 STATUS LINES

There are three status lines on the IDS display. One is a general status line and can be found at the bottom of the display. It is the narrow box extending right across the screen. The other two are shorter (half a screen) and are found under the data areas that they pertain to. These are called "Status Line", "RIDS Status Line" and "SAR Status line", respectively.

6.1 STATUS LINE

This window is used strictly for feedback and user input. When you are prompted, the prompt, and input will be within this window. When there is no input, the status line will display the name of the region the cursor is in (for example, it will say "RIDS DATA AREA" when the cursor is in the RIDS data area.) and some information pertaining to that area.

In the case of the button areas, the status line will display the name of the button, as well as the region you are in.

When in the RIDS data area, and the region is in RIDS mode, then you will receive the range of the cursor from the center of the RIDS display (in pixels), the bearing of the cursor (in degrees), and the value of the pixel under the cursor after applying the user chosen filter (1 by 1, 3 by 3, or 5 by 5). If the region is in SAR mode, then the X and Y coordinates of the cursor with respect to the origin of the image is displayed. This is also the same for the SAR data area.

6.2 RIDS STATUS LINE

This status line will display the angle that the RIDS image has been rotated (from 0 degrees being east), the number of the image, and the source of the image.

The number of the image is a count of the number of images displayed from the start. While normally the start is at the beginning of the tape, it is possible that it is in the middle of the tape. To ensure that the number is relative to the beginning of the tape, rewind the tape using the rewind option after initially running this program.

The source of the image is taken from the header of the RIDS data images as they are read in. It is quite possible that this source (which includes the date and time the image was written) may not change (ie when the real-time log program is used), or changes drastically (ie using the same tape for a different set of data on a different day).

NOTE: This only applies when the RIDS data area is in RIDS mode. If it is in SAR mode, it acts just like a SAR status line, except for the RIDS data area.

CA1
DT501
86
S63
c.2

6.3 SAR STATUS LINE

The SAR status line displays such information as the X and Y coordinate of the region being displayed, the width and height of the image being displayed, the flag values, and the filename.

The X and Y coordinates (following X: and Y:) are relative to the origin of the image, or the start of the file. If these coordinates are not within the image, the entire window will show some pretty useless (though consistent) garbage. These values can be set using the vertical (to set Y) and horizontal (to set X) move options.

The width and height (following W: and H:) are just that, the width and height of the image region being displayed in the window. These values can be set by the zoom option. If the width and height of the region being displayed does not entirely fit within the image, then useless garbage will appear.

The flags indicate whether the SAR image has been flipped, mirrored, or rotated. These flags follow F: in the status line and are displayed in the following order: flipped, mirrored, rotated. If the flag (or option) is activated, then the letter F, M, or R will be displayed in its respective place (F, M, R stand for Flipped, Mirrored, and Rotated). If the flag (option) is deactivated, then a minus ('-') sign is displayed.

The filename is just that, the file from which the current image being displayed is taken from. This will be a valid UNIX pathname (ie /dev/rmt0 if the image is being read off of tape).

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